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ABSTRACT

Educators often fail to implement improved teaching systems because they lack a method of choosing among instructional alternatives. The Rand Coporation is developing for the Air Force a means--called Method of Designing Instructional Alternatives (MODIA)--whereby instructors can select a preferred instructional system. Using MODIA, one begins by designating the personnel to be equipped with defined skills and by identifying the training requirements and instructional objectives. Instruction is planned, implemented, and validated. The first step involves the specification of inputs, including instructional plans, teaching strategies and learner characteristics. System design proceeds by linking instructional strategies to curriculum units, by developing configurations of personnel, media and facilities, by charting student flow through the course, and by analyzing the cost of each component. The results of a completed design cycle using MODIA for design and cost analysis of an innovative Air Force course are presented as an illustration of the method. (PB)

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Robert L. Petruschell and Polly Carpenter

A Report prepared for

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PREFACE

This is one of four interrelated reports describing Rand work for the Air Force to date on the development of methodologies for designing programs of instruction. The reports in the series are:

R-1018-PR, *An Overview of MODIA: A Method of Designing Instructional Alternatives for Air Force Training,* Polly Carpenter.

R-1019-PR, *The MODIA Decision Process for Developing Strategies of Air Force Instruction,* Polly Carpenter and Barbara Horner.

R-1020-PR, *The MODIA Questionnaire for Curriculum Analysis,* Rudy Bretz.

R-1021-PR, *MODIA Applied in the Design and Cost Analysis of an Innovative Air Force Course,* Robert L. Petruschell and Polly Carpenter.

The first of these provides an overview of the methodologies being developed; the second and third describe some of the major analytical tools used to provide inputs to the design process; and the last sets forth the results of a completed design cycle, parts of which were carried out manually, applied to a specific course in Air Force technical training.

This work has been conducted under a Rand project entitled *Analysis of Systems for Air Force Education and Training.* Emphasis has been on the use of technology in designing instruction for formal technical training or for higher education, as at the Air Force Academy. The results will support the activities of the Director of Personnel Plans, Headquarters USAF; DCS/Technical Training and the Training Development Directorate, Headquarters Air Training Command; and the Air Force Human Resources Laboratory, especially the Technical Training Division. It will be of particular interest to those working on the Advanced Instructional System.

This report is part of a continuing Rand effort to apply systematic methods of analysis and synthesis to issues and problems in education and training. Related studies have concerned Air Force pilot training and management of the pilot force, evaluation of programs of compensatory education, design of information systems for local school districts, and other diverse concerns. A special bibliography of Rand work in education is available on request.

We wish to thank our Rand colleagues Edmund Brunner and Stephen Mayo for their excellent comments and suggestions for improving this report.

SUMMARY

This report describes a methodology for the design and cost analysis of an instructional system, illustrating the processes with a specific example of innovative instruction. The methodology will assist those who are planning to implement new courses of study or new teaching methods in an existing or planned teaching institution. The processes described here are part of a set of procedures that Rand has been developing for the Air Force, to ease the task of implementing needed changes within Air Force education and training institutions. (For an overview of the design process, see R-1018-PR.)

Many new ways of teaching and much instructional technology have been developed and validated for their contributions to effective instruction, yet these innovations have seen but little implementation in existing schools. A prime reason for this is that the designers of instruction, even when they are not also burdened with the task of classroom teaching, (1) are not sufficiently familiar with the new systems to plan their implementation, and (2) lack tools to assist them in planning the implementation of those systems with which they are familiar. The objective of the Rand research is to develop methodologies for designing systems for instruction, so that promising alternatives are not overlooked, and so that the education planner can assess these alternatives rapidly for their utility to him. This approach points the way to improved instructional systems in a wide range of situations.

Throughout, it is assumed that the learning objectives of the course are given so that the work will complement the current Air Force concern with the *systemization* of instruction, described in Air Force Manual 50-2, *Instructional System Development.* Systemization is a series of interrelated steps leading to the conduct and evaluation of instruction. After analyzing the requirements for system operation in terms of numbers of personnel to be equipped with defined job skills, the training requirements are identified and the objectives of instruction are developed. At this point, actual instruction must be planned and implemented for validation. This is the step on which Rand has been working.

In this report, we demonstrate systematic methods for using the characteristics of learners, curricula, and teaching institutions to direct the design of instructional systems and to estimate their resource requirements. The demonstration is carried out by means of a concrete example, a course in basic still photography to be given to airmen at an Air Force Technical School. This is a shortened and revised version of an actual course given at the Technical School at Lowry Air Force Base. It was chosen because it included enough varieties of instruction—from classroom discus-

sion to student performance out of doors—to permit the prescription of varied school situations and teaching strategies.

First, the inputs to the design process were prepared. The Plan of Instruction for the course provided a detailed description of the content and sequencing of the subject matter. This was revised and then used as a basis for answering the curriculum analysis questionnaire.[1] Data from the curriculum analysis characterized each unit of subject matter in terms of the category of instruction (such as drill or demonstration) and any special requirements for resources, such as cameras for students to practice with.

Concurrently, a teaching strategy was formulated, using a logical decision process.[2] This strategy specified that variable pacing would be used throughout the course and, for each category of instruction, designated the controller of the pacing, among other things. Plans for scheduling and conducting reviews, examinations, and discussion sessions were also established.

The expected learner population was characterized in terms of the distribution of student learning rates. No further characterization was necessary, since the strategy called for all students to study essentially the same subject matter in the same sequence, regardless of learning capability or prior learning.

The criteria for designing the instructional system in the example were established with a view towards imposing as few limitations on innovation as possible. The design was not to be constrained by resource limitations of any type. On the other hand, while all kinds of resources were to be considered readily available, those chosen were to be of moderate cost. The overriding criterion was the saving of student time, because prior work has shown that student time is the largest component of the cost of technical training. Thus, no queues would be formed as students waited for instructors or other resources to become available.

In the general case, the next step would be to analyze local resources and constraints, because the precise configurations that would be chosen would be heavily influenced by existing facilities and other resources. But, although the course would be given at an existing Air Force Technical School, we assumed that all resources required were to be provided new. This is a somewhat unreal assumption, but does serve a useful purpose as an initial trial in that it forced the explicit consideration of all course requirements. It also resulted in a maximum cost case, a point of departure for the consideration of other, possibly more feasible, alternatives.

At this point the necessary inputs had been specified and the system design process could begin. Several steps were involved. First, the categories of instruction were used to tie instructional strategy to each unit of instruction described in the curriculum analysis.

Next, specific configurations of personnel, media, and facilities for conducting each unit of instruction had to be designed. Because they are so interrelated, these were all dealt with simultaneously. Since we had assumed that individual, variable pacing would be used throughout and that no student would have to wait for resources, it seemed reasonable to specify that each student would have free access to

[1] See R-1020-PR.

[2] See R-1019-PR.

texts, media programs, and hardware, as necessary. Self-contained, portable systems were proposed as the most appropriate and least expensive solutions.

All of the media hardware required—sound-motion film viewers, silent-motion film viewers, sound-slide set projectors, and teaching machines—were found to be available relatively cheaply in easily portable models. Therefore, we developed the scheme of a central storage place where portable media hardware and required software would be available to students on demand. Students would work in a general-purpose carrel area, a room containing only simple carrels and chairs, adjacent to the storage place. The carrels—simple enclosed individual work tables or desks with shelves—would be supplied with electric power. Students would come to the carrel area, check out hardware and software appropriate to the instruction they were going into, take the material to an open carrel, use it, and return it either on completion of the unit or at the end of the day. It was assumed that a clerk/monitor, responsible for issuing and receiving materials, would be present at all times.

Individual, fully equipped darkrooms, large enough to handle one student and possibly an instructor, and in sufficient quantity to meet peak demands, were specified for events requiring the use of darkrooms.

Students were required to meet with instructors for several purposes: for tutoring, for discussing prior media presentations, and for examinations. Tutoring rooms large enough to hold one student and one instructor were proposed for these activities. Each room would be equipped with a desk, a table, two chairs, and the aids and devices required for the instruction.

Each configuration of teaching location, media hardware, and instructors was then keyed to the appropriate instructional units.

Next, the flow of students through the course was simulated by a computer model. In this model each student was assigned a learning rate by a random draw from the assumed distribution of student learning rates. Then each student moved through the course at his assigned rate—except that some instructional units were of fixed duration, and for others upper limits were assigned to the amount of time that a student could spend. As each student entered a particular unit of instruction, he generated requirements for the resources associated with the conduct of that unit.

The costs of the resources required were then analyzed in considerable detail. A summary of these costs is shown in Table 1 below. *Note that the bulk of the investment cost goes for facilities which would normally already be available at an existing school, except for whatever remodeling is needed.* The annual cost of personnel, however, reflects the use of instructors in a tutorial mode, occasioned by the assumptions that each student must proceed at his own pace and must never have to wait for resources. This cost analysis suggests that considerable savings in this area might accrue if even greater use were made of media.

This exercise has made contributions in two major areas. The most obvious contributions have to do with the specific example used to illustrate the design process. The instructional program resulting from the application of a highly individualized teaching method to the course in basic photography has been shown to have a cost similar to (though higher than) the cost of photography courses taught in ways more representative of current Air Force practice.

More importantly, the rates of utilization of instructional resources (shown in detail by the outputs of the student flow model) and the distribution of costs among

Table 1

COST OF INNOVATIVE PHOTOGRAPHY COURSE

(in $ thousands)

Item	Initial Investment	Annual Operating
Facilities and related equipment	2162	157
Media hardware and software	215	78
Personnel	395	1548
Other	27	45
Total	2799	1828

elements of the instructional program indicate that relatively minor changes could effect appreciable savings without impairing the individualized nature of the instruction. In particular, a slight relaxation of the design criteria to permit some queuing and a greater use of media for classroom instruction and demonstration would reduce the facilities and equipment required on the one hand and the number of instructors needed on the other. The effects of such changes could be explored in a few days, using the tools already developed. The same tools would permit rapid examination of other variations that might be of interest.

The exercise has implications broader than the specific example, however. Perhaps of primary importance to the design team is the confidence that has been engendered in the feasibility of developing systematic approaches that are of general applicability to the design of instruction. Although there are several a n which further basic analysis is needed, the team found that at almost ever t it was possible to resolve issues by applying simple logic and rules of thumb. In addition, despite the developmental nature of most of the effort that went into working out the example, the total time required was on the order of six weeks.

A second significant result is that going about the design of programs of instruction in a systematic way does, indeed, encourage the examination of alternative approaches to instruction, as discussed above. The provision of details on resource utilization rates and student flow, *which can be traced directly to decisions regarding design criteria and teaching method*, encourages the designer to reexamine these prior decisions with an eye, for example, to improving the efficiency of the program of instruction.

And finally, as we worked through the design process we also gained important insights into the workings of an instructional program that might not otherwise have occurred to us. For example, it became evident that the needs of students in highly individualized courses such as this one would most conveniently be met by designing facilities, materials, and equipment for use in small units and that some degree of portability was highly desirable. In addition, because the cost of successive use of recorded materials is low, in a course such as this one with high student loads and individual use of instructional resources, instruction presented by recorded media is an inexpensive alternative to the face-to-face tutorial.

CONTENTS

I. INTRODUCTION

Many new and demonstrably preferable systems for teaching have been developed and validated, but few have been implemented in today's classrooms. Designers of such systems are typically teachers so burdened with day-to-day classroom problems that they are unable to supply the impetus and guidance essential for implementation. Such decisions are consequently relegated to the teaching institution, where they are made based almost exclusively on intuition and judgment. At that level, the tendency to maintain the status quo usually overrides, and few changes are made.

Those innovations that do eventually find their way into the instructional world do so when dedicated people with faith in the merits of a particular idea are able to convince institutions of the correctness of their approach. A lengthy system design process with little but intuition for guidance must follow. An improved instructional system may result, but seldom is there assurance that other alternatives would not have yielded still more improvement.

No instructional system designer has first-hand knowledge of all available alternatives—and if he had, he does not have a method for choosing among them. Rand is developing a set of methods that will provide this knowledge, under the overall name of MODIA (A Method of Designing Instructional Alternatives). When this work has been accomplished, many of the problems mentioned above will be solved and the design and choice process that now takes months and even years can be shortened to days or weeks, with greater likelihood of producing comprehensive, coherent, and relevant instructional systems.

This report was prepared to illustrate by means of a single example how such a systematic method can be developed and used to select preferred instructional systems. The example is built around a hypothetical course to teach the fundamentals of basic photography to Air Force enlisted personnel. The example is rich enough to illustrate the general analytical approach; but no single example can possibly reflect all of the many potentialities and, of course, this one does not.

Much of the research drawn upon here is reported in the three other reports cited in the Preface. The present intent is to show how all of these methodologies are used to help configure instructional systems and to estimate the resource implications of those systems. Each tool plays an essential part, but here the focus is on developing the methods of instructional system synthesis and cost analysis to answer the question: Given a set of policies, a teaching strategy, analyses of a curriculum, and a group of students, what will the instructional system look like and what will it cost?

Ultimately, much of the process described here will be automated, so that the resource implications of a wide range of alternative policies and strategies can be examined rapidly and with sufficient ease to encourage education planners to search for preferred instructional systems as a matter of routine.

Since the research necessary to make all of this possible has not been completed, this is a progress report in which the suggested approach to planning instructional systems is described, completed research is indicated, and that remaining to be done is identified. Also, the example presented here demonstrates many of the benefits to be gained from this kind of an approach to planning instructional systems.

AN OVERVIEW OF THE DESIGN PROCESS

The methods for designing instructional systems that Rand is developing will provide information such as course length, student loads and flows, and requirements for resources and funds for alternative instructional systems. First, inputs that characterize the teaching institution, the student population, and the curriculum must be stipulated. This requires the designer to make detailed and explicit statements in several areas. The expected student population must be characterized in terms that will affect the way the course will be taught. Next, institutional objectives, such as a requirement for a fixed number of weeks of training for every student, or for every graduate to exhibit mastery of the same subject matter, will be stated with the help of a short questionnaire.

A more elaborate, branching questionnaire (the curriculum analysis) will be used to guide the designer in providing a concise but detailed description of the proposed course of study. The order in which the subject matter will be presented and any special resources that will be required to teach it will be indicated. The classes of communication media that might be used at various points in the course will also be elicited from answers to this questionnaire.

Next, the designer will specify a teaching method for each type of instruction identified in the curriculum analysis. To accomplish this, he is guided through a decision table by a time-shared computer program which will ask him to make necessary strategy decisions in a logical sequence. An accompanying manual will help him by presenting the pros and cons and important implications of each choice.

Criteria for designing the instructional system will be provided by the teaching institution. Minimum cost, minimum course length, maximum graduate output per unit of time, and maximum use of communication media are examples of criteria that might be specified.

Resources already on hand that could be used in teaching the course are next inventoried by means of a questionnaire. Classroom space and trained personnel will be enumerated, along with other resources.

The process of system synthesis can now begin. Each unit of instruction (described in the curriculum analysis) will be linked to the teaching strategy chosen for the appropriate type of instruction. A statement of the characteristics of the physical plant required and the method of operating the course will be prepared.

Student flow through the course will be simulated to determine the requirements for resources: teachers, communication media, facilities, and the like. The requirement for resources will be translated into an estimate of the dollar cost required to procure and maintain these resources and the final output will be prepared. The output—course length, student loads and flows, and requirements for resources—will be organized to highlight the relationship between course characteristics and the requirement for specific kinds of resources. Formalization of method and automation will make it possible for instructional system designers to examine a range of possibilities before choosing the one that best meets design criteria.

Figure 1 illustrates the instructional design process schematically.

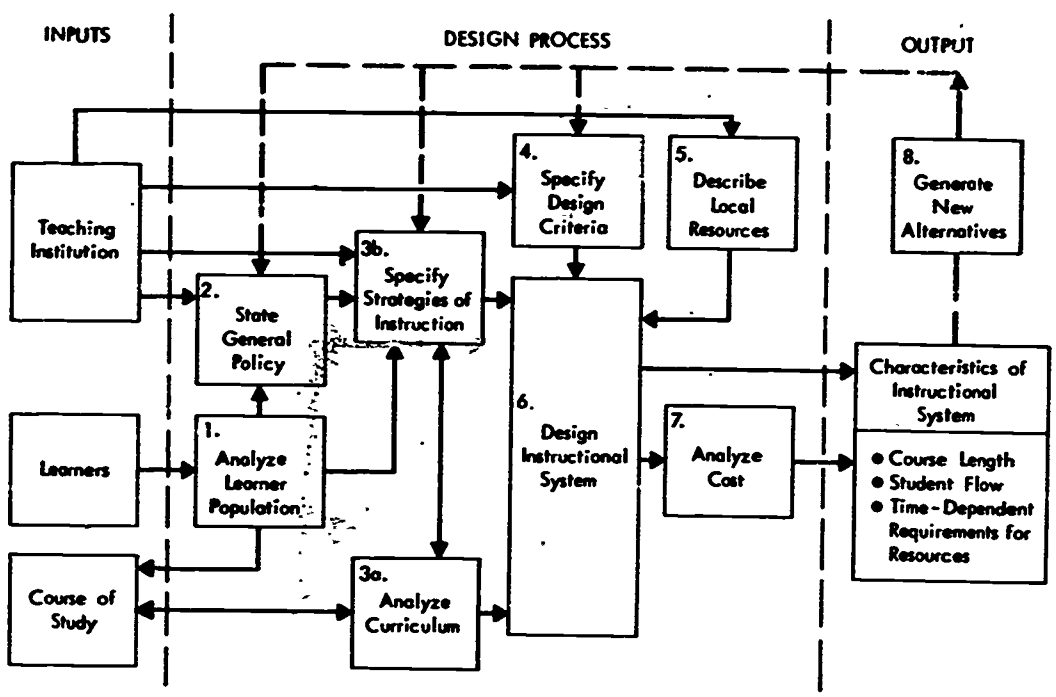

Fig. 1—The instructional design process

THE EXAMPLE

An instructional system designer, who may be a teacher, an educational administrator, or a specialist in the design of instructional systems, is confronted with the problem of developing a system for teaching basic still photography to Air Force enlisted personnel. The course will be presented at an existing Air Force Technical Training Center and is required to produce on the order of 2,600 graduates annually.

While it is certain that the final choice of a system will be influenced by resource availability and institutional policy, the designer is asked not to constrain himself with either of these at the outset. He is directed specifically to explore the possible costs and benefits of using novel teaching strategies and communication media to the extent he thinks feasible. In order for the designer to say anything meaningful in response to his assignment, he obviously needs to consider a range of possible system configurations and instructional strategies. The example presented here demonstrates how he would examine one of these.

Teaching basic photography to Air Force enlisted personnel was selected as an example for several reasons. A detailed curriculum statement, from which the example curriculum was constructed, was available from the Air Force. The course itself was straightforward in terms of subject matter and at the same time offered a fairly wide range of different kinds of teaching problems, from basic classroom presentation and discussion to application of skills both in the darkroom and taking pictures out of doors. Each of these different types of instruction offered a wealth of material for the application of novel teaching techniques.

The example instructional system is characterized by a relatively large student load and graduate output: an average load of 100 students and an annual graduate output of 2,600. Each student determines his own rate of progress through the course. While the average student completes the course in two weeks, the slower students can take up to three weeks and the brighter ones finish in as little as one. Extensive use is made of various kinds of communication media for instruction, review, and evaluation of student progress.

Media are used in several different modes, ranging from pure demonstration to actual response-pacing of instruction. Because of the individual pacing requirement, media are always assigned to students on a one-to-one basis. Some instructional units in the course require interaction between students and live instructors. When this is the case, no more than one student will be in contact with the same instructor at the same time. Each student essentially has his own personal tutor.

In reality, there would probably be a limitation on the number of instructors and other resources that could be made available, which would mean that students might be forced to wait at various points in the course. In the example, no such constraints were imposed; hence, the only factor governing the individual student's rate of progress was his ability to master the subject matter, except that generous upper limits might be imposed on the time a student spends on a particular unit.

II. PREPARING THE INPUTS FOR SYSTEM DESIGN

The instructional system design method presupposes the availability of considerable input information, most of which has already been mentioned. To set the stage for designing a specific instructional system, each of the required inputs will be described briefly.

CURRICULUM DESCRIPTION

The following topical outline describes the content of the hypothetical course in basic photography that will be used as an example around which to design an instructional system. This course is based roughly on the first block of lessons in a similar course on photography offered at Lowry Air Force Base, but does not represent any actual course. The sample course is quite rich in that it offers considerable opportunity for the introduction of innovative teaching methods and the use of various kinds of communication media in addition to live instructors.

Outline of a Course in Basic Photography

Lesson 1: Introduction

Orientation to the photography field, the course outline and the study methods to be used in the course. Elementary photographic theory: exposing film, developing, printing. The basic parts of the 4x5 press camera.

Lesson 2: Care and Operation of the 4x5 Press Camera and Accessories

Familiarization with the camera and accessories, safety procedures, procedures of operation. Each student will produce 6 Polaroid pictures.

Lesson 3: Exposure Theory, Film Speed, and Light

The correlation of film speed, diaphragm opening, and shutter speed in producing proper exposure; lighting conditions, subject reflectivities and scene brightness range; the use of exposure guides, incident and reflected light meters, gray cards, etc. The USASI exposure system; the exposure problems in using the bellows extension; the effects of lens opening and focal length on depth of field and depth of focus. Each student will produce 8 acceptable pictures from 12 exposures, each representing a different f/stop-shutter speed combination.

Lesson 4: Film and Film Processing

The loading and unloading of cut-film holders; the basic theory of photographic processing; the procedure of developing the negative; the procedure of making the print. The production by the student of 4 correctly exposed and developed negatives out of 5 tries, and the production of an acceptable print from each acceptable negative.

Lesson 5: Principles of Good Composition

The theory of good and bad picture composition. Practice in recognizing both good and bad composition; practice in producing pictures with good composition.

Below, the topical outline has been converted into a detailed breakdown in which each instructional activity is separately described, its objectives are specified, and its probable duration in minutes is shown, based on the time requirements of conventional instruction. In the detailed breakdown, topics are described in terms of *learning events*, a term which from here on will be used to refer to a single unit or item of instruction. The entire course consists of ordered learning events grouped into sets called *lessons.*

Learning Objectives for a Course in Basic Photography

Lesson 1: Introduction

Learning Event 1 (average time, 35 min.): An introductory presentation covering: a general introduction to photography as a career field, the study methods that will be used in the course, and an outline of overall course content. The student forms an image of himself using photography in his service years and also in his future life, as a possible career, as a tool in other careers, and as a means of creative recreation. Students will not be examined (formally evaluated) for mastery of this material.

Learning Event 2 (average time, 120 min.): A presentation to introduce the student to elementary photographic theory.

On an exam the student will be able to list the three basic steps in producing a photograph, naming the major pieces of equipment involved.

Learning Event 3 (average time, 120 min.): A demonstration of the procedure of taking a picture with a 4x5 press camera, developing the negative, and making a print. The purpose of this event is to enable the student to begin to practice the demonstrated skills in later learning events. Not to be evaluated.

Learning Event 4 (average time, 75 min.): The students are introduced to the basic components of the 4x5 press camera.

To demonstrate mastery of this event on an exam, the student will first be able to list the three most important safety precautions to take in handling the camera. Next, given a diagram of the 4x5 Speed Graphic, he will be able to recognize and name the lens, shutter, diaphragm, focusing mechanism, film holder, bellows, etc. Finally, given the name of any of these elements, he will be able to locate it on the diagram. If it is externally visible he will be able to locate it on an actual camera or photograph thereof.

Lesson 2: Care and Operation of the 4x5 Press Camera and Accessories

Learning Event 1 (average time, 30 min.): A presentation on the care and use of the camera and accessories. In addition to the basic components of the camera, the Polaroid adapter, presslock, cable release, exposure meter, dark cloth, and tripod will be explained. Not to be evaluated.

Learning Event 2 (average time, 120 min.): A presentation in which the student will learn the basic steps in operating the 4x5 press camera with the Polaroid adapter.

On an exam, given a diagram of the camera, the student will be able to list the proper steps necessary to open and close the camera, focus an image on the ground glass, attach and detach the Polaroid film holder, set up the tripod, affix the camera to it, etc.

Learning Event 3 (average time, 30 min.): Students will see the procedures they have heard described demonstrated on an actual camera. Not to be evaluated.

Learning Event 4 (average time, 150 min.): Each student will be provided with camera, Polaroid film adapter, and tripod. Out of doors and following the demonstration he has seen, he will produce 6 pictures. An instructor will evaluate student pictures as they are produced.

On an exam the student should be able to take 6 pictures under like conditions, of which 4 will be acceptable in the opinion of the examiner.

Lesson 3: Exposure Theory, Film Speed, and Light

Learning Event 1 (average time, 35 min.): In this presentation, the students will be introduced to the theory of photographic exposure. The characteristics of the various kinds of film will be described, with emphasis on film speed.

On an exam, the student will be able to correctly relate the terms "fast" and "slow" both to lenses and to film emulsion. Given the name and/or number of one of the 4 most used kinds of film, he will be able to state the ASA rating. He will be able to rank the 4 films in order of speed (sensitivity).

Learning Event 2 (average time, 60 min.): In this presentation, the student will go further into the theory of photographic exposure. The different types of exposure meters will be introduced and the use of meters, exposure guides, and the gray card will be explained.

On an exam, the student will be able to acceptably explain the functions of the incident light and reflected light meters. He will be able to state the conditions under which exposure guides are useful; he will be able to explain the purpose and advantages in using the gray card.

Learning Event 3 (average time, 30 min.): In this presentation, students will be introduced to the USASI exposure system.

On an exam, the student will be able to correctly list the steps in the USASI system, and will be able to identify two of its advantages over other systems.

Learning Event 4 (average time, 30 min.): The students will observe a demonstration of the proper procedures in the use of the exposure meter, gray card, and camera exposure controls. The instructor will take several Polaroid pictures of the same subject to show the effect of good and poor use of the exposure meter, and the effects of changing diaphragm opening, shutter speed, and film speed on exposure. Not to be evaluated.

Learning Event 5 (average time, 60 min.): In this presentation, the student will go further into the theory of photographic exposure.

To show mastery on an exam he will be able to explain the meaning of the term "scene brightness range." He will be able to state the reciprocity law. Given an unlabeled characteristic curve for a typical film, he will be able to identify the two coordinates, and explain in his own words the meaning of the curve.

Learning Event 6 (average time, 60 min.): In this presentation, the student will encounter the basic concepts underlying the theory of lenses. Lens opening, focal length, sharpness, depth of field, and depth of focus will be discussed.

On the exam, the student will be able to define these terms and to state the effect on depth of focus or field when the lens is (1) opened or (2) closed, and when (3) the lens is replaced by one of greater focal length, and (4) the lens is replaced by one of lesser focal length.

Learning Event 7 (average time, 120 min.): A "follow-me" step-by-step demonstration in which the students will experience the use of exposure aids of various types including exposure guides, exposure meters of both the incident and reflected light types, gray cards, etc.

Mastery will be demonstrated on an exam by the student's being able to use these aids to produce properly exposed photographs without supervision or guidance.

Learning Event 8 (average time, 45 min.): In this presentation the proper procedure for exposing photographs of small objects when the bellows extension is in use will be discussed.

On an exam, the student will be able to state the major exposure problem in using the bellows extension, its cause, and to explain the procedure for overcoming it.

Learning Event 9 (average time, 340 min.): The students will individually take cameras into the field and, using the equipment and techniques they have learned, take Polaroid photographs at various f/stop and shutter speed combinations.

On an exam, mastery of Lesson 3 will be demonstrated by the ability to produce 8 acceptable photographs from 12 exposures, each of which represents a different f/stop-shutter speed combination.

Lesson 4: Film and Film Processing

Learning Event 1 (average time, 15 min.): A short introductory presentation on the principles of cut-film handling and processing. It will not be evaluated.

Learning Event 2 (average time, 30 min.): A follow-me demonstration, in which each student will have in his hands a piece of cut film and a cut-film holder as he watches and follows a step-by-step demonstration of the loading of a cut-film holder.

To demonstrate mastery, on an exam he should be able to load a cut-film holder 5 times in succession without error.

Learning Event 3 (average time, 30 min.): A demonstration in the darkroom of the methods and procedures involved in processing a cut film from removal from the holder, through the development process, to the making of the final print. Not to be evaluated.

Learning Event 4 (average time, 15 min.): A brief explanation of the theory behind the procedure the students have just witnessed.

On an exam, the student should be able to state roughly the chemical composition of the film emulsion, the composition of the developer, and describe what happens when the developer works on the film. He should be able to state the composition of the hypo and the stop bath and explain in general terms how each of these performs its function.

Learning Event 5 (average time, 60 min.): Each student takes 2 pictures and develops the cut film. Here he will get a chance to put into practice the process of developing film that has been demonstrated and explained to him.

Given a familiar 4x5 press camera and familiar film stock, to show mastery of this event, he will be able to expose and correctly develop a negative under similar conditions, to the satisfaction of the instructor.

Learning Event 6 (average time, 60 min.): The activities in this learning event will continue the work begun in the previous event. The film that was developed will, at this point, be used by the student to produce a finished negative and a print.

To prove mastery on an exam, the student should be able to produce an acceptable print from each of 4 acceptable negatives.

Lesson 5: Principles of Good Composition

Learning Event 1 (average time, 90 min.): This presentation will discuss the principles of good picture composition. The role of lens focal length in composition will be included.

To demonstrate mastery, on an exam the student will be able to list 4 faults of bad composition to avoid, and 6 characteristics of a good composition which are not necessarily present in an uncomposed picture.

Learning Event 2 (average time, 30 min.): The principles discussed in the previous event will be demonstrated. A camera will be used to frame compositions of various subject matter, in various ways, showing the effects of neglecting to avoid the faults of bad composition, and of following the rules of good composition. Not to be evaluated.

Learning Event 3 (average time, 30 min.): The students will be shown a series of photographs, some professional, some amateur, chosen to illustrate various applications (or lack of application) of the principles discussed in the previous events. The students will be asked to critique each photograph, and to point out the good or bad elements it contains. Not to be evaluated.

Learning Event 4 (average time, 30 min.): The instructor will demonstrate the technique of framing a picture using a large 11x17 printed picture and 2 L-shaped framing masks. Not to be evaluated.

Learning Event 5 (average time, 30 min.): The student performs the following study assignment: Given an 11x17 picture and 2 L-shaped masks (maximum frame size: 3 in.) the student will frame and draw on the picture 4 good compositions (marking them G) and 4 bad compositions (marking them B). He will be prepared to analyze why the good ones are good and the bad ones are bad.

On an exam the student will be judged (by the examiner) to have mastered this event if he is able to frame 4 pictures under similar conditions, 2 that are "bad" composition, and 2 that are "good," and to give at least 1 satisfactory reason why each is either bad or good.

Learning Event 6 (average time, 60 min.): The task outlined in event 5 is repeated in the classroom. Each student frames only 1 good and 1 bad composition on a 3 ft by 4 ft picture, with proportionately sized framing masks. Each student will discuss his compositions with instructor and/or fellow students. Not to be evaluated.

Learning Event 7 (average time, 180 min.): The students will go outside with press cameras and will each take 10 pictures. Each student will develop his negatives and make contact prints.

On an exam, under similar conditions he must make 5 photographs and prints, 4 of which show proper exposure and processing and acceptable composition.

CURRICULUM ANALYSIS

With the detailed statement of the hypothetical course in hand, further specificity is obtained with the curriculum analysis questionnaire. The questionnaire, by systematically asking a number of specially tailored questions, helps the course planner to think in systematic terms about his course and to provide, for the most part, a concise, concrete (in most cases quantitative) description of the characteristics of exactly what he wants to teach. The result is a curriculum analysis in the sense that each learning event is taken completely apart by the questionnaire and the characteristics of each part are described explicitly.

The curriculum analysis covers only basic instructional events. It specifically excludes any mention of reviews, evaluations, or discussions. These items are introduced when setting instructional strategy. The information about curriculum elicited by the questionnaire will be integrated with the various other inputs to synthesize an instructional system and to estimate the student flow and resource implications of that system.

For each learning event, the planner answers a two-part questionnaire and enters the results on a standard form. The answers to the questionnaire for the basic instructional learning events are shown in Table 2. The coded information shown in Table 2 is explained in the master code list, Appendix A, as well as in the text discussion.

The first part of the questionnaire seeks a largely quantitative description of each learning event, while the second part helps the planners select the kind of communication media, if any, that would be appropriate for the particular event.

The normal procedure for filling out the curriculum analysis form is to consult the detailed outline of the course, read the description of the first learning event, answer each question in parts I and II of the questionnaire, enter the answers on the form, and proceed to the next learning event. This approach is dictated by the

Table 2

CURRICULUM ANALYSIS DATA SHEET FOR BASIC INSTRUCTIONAL LEARNING EVENTS

	Lesson 1				Lesson 2				Lesson 3									Lesson 4						Lesson 5						
	Learning Event Number																													
Parameter	1	2	3	4	1	2	3	4	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	1	2	3	4	5	6	7
Lesson Analysis Questions																														
x(1) Learning event time (minutes)[a]	35	120	120	75	30	120	30	150	35	60	30	30	60	60	120	45	340	15	30	30	15	60	60	90	30	30	30	30	60	180
x(2) Housekeeping time (minutes)[a]	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
x(3) Interrelated concepts or skills	0	0	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1
x(4) Type of special learning event	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
x(5) Learning event category code	1	1	11	2	2	2	11	9	1	1	1	11	1	1	12	2	9	1	7	11	1	9	9	1	11	4	6	4	4	9
x(6) Minimum performance rate an objective	--	--	--	--	--	--	--	0	--	--	--	--	--	--	0	--	0	--	1	--	--	0	0	--	--	0	--	0	0	0
x(7) Team size	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Additional support personnel required:																														
x(8) Instructor level	--	--	0	0	0	0	0	--	--	--	--	0	--	--	--	0	--	--	--	0	--	--	--	--	0	--	0	--	--	--
x(8) Student assistant level	--	--	0	0	0	0	0	--	--	--	--	0	--	--	--	0	--	--	--	0	--	--	--	--	0	--	--	--	--	--
x(9) Instructor required for knowledge of correct responses	--	--	--	--	--	--	--	1	--	--	--	--	--	--	1	--	1	--	1	--	--	1	1	--	--	1	--	0	1	0
x(10) Supervision required for safety	--	--	--	--	--	--	--	1	--	--	--	--	--	--	1	--	1	--	--	--	--	1	1	--	--	--	--	--	--	3
x(11) Special area required to produce presentation	--	--	4	0	0	0	0	2	--	--	--	2	--	--	2	0	2	--	--	4	--	4	4	--	2	--	--	--	--	2
x(12) Selected responses satisfactory for evaluation	--	--	--	--	--	--	--	0	--	--	--	--	--	--	0	--	0	--	--	--	--	0	0	--	--	1	--	0	0	0
x(13) Special equipment required to produce presentation	--	--	1	1	1	1	1	1	--	--	--	1	--	--	1	1	1	--	--	1	--	1	1	--	1	--	--	--	--	--
x(14) Source of special equipment if required	--	--	4	4	4	4	4	4	--	--	--	4	--	--	4	4	4	--	--	4	--	4	4	--	4	--	--	--	--	--

(Continued)

Table 2--continued

x(15) Number of viewers who can see one face-to-face presentation	50	50	10	50	50	50	10	--	50	50	50	10	50	50	5	5	--	50	50	10	50	--	--	50	5	--	5	-	--	--
x(16) Length of one presentation, demonstration, or presentation of problems and directions in minutes	25	60	90	50	20	100	30	10	30	50	25	25	50	50	30	35	10	15	20	25	15	5	5	75	20	--	15	5	0	10
x(17) Special materials required for performance	--	--	--	--	--	--	--	1	--	--	--	--	--	--	1	--	1	--	1	--	--	1	1	--	--	0	--	1	0	--
x(18) Learning event regularly scheduled	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
x(19) Subject matter to be formally evaluated	0	1	0	1	0	1	0	1	1	1	1	0	1	1	1	1	1	0	1	0	1	1	1	1	0	0	0	1	0	0
x(20) Months between revision of curriculum content	12	24	60	60	60	60	48	48	12	60	60	60	24	60	48	48	60	48	48	60	36	48	48	60	60	60	60	60	60	60
x(21) Appropriate media class	2	5	1	5	5	5	4	5	5	5	5	5	2	5	5	5	5	5	4	4	5	5	5	5	5	5	1	5	0	5

[a] In this example, learning time x(1) includes housekeeping time x(2).

interrelationships among the questions themselves and among the questions and the learning event descriptions.

An abbreviated description of each question is shown in the left-hand column of Table 2. Each column contains the answers to these questions for a specific learning event. Note that not all questions are answered for each learning event. Learning events are shown in order from left to right and grouped by lesson. Variables x(1) and x(2) indicate the time it will take the average student to accomplish the event and the extra time required for performing housekeeping tasks, respectively. Housekeeping would include check-in and check-out of equipment, clean-up, and initial set-up time. For simplification, these two times have been included in x(1) in this example.

x(3) asks whether or not the event involves the mastery of interrelated concepts or skills. If it does, it is considered relatively difficult or complex; if not, relatively easy or simple. Later it will be possible to tailor teaching strategies differently, depending on the answer to this question.

x(4) permits the course planner to specify learning events that will not be encountered by all students. This gives him the option of including remedial instruction for slow students and enrichment events for bright students while the average students proceed through the basic course only. None of these options has been exercised in the example. Instead, each student encounters every learning event.

x(5) identifies each learning event as belonging to one of 12 categories of instruction so that teaching strategy may be specially tailored to each if desired. For example: Code 1 indicates no drill or practice and no special equipment or facilities required to produce the presentation; code 9 is drill or practice of individual skills requiring the use of special equipment, facilities, or both; and code 11 implies a pure demonstration of individual skills that requires the use of special equipment and/or facilities or both.

x(6) is used to indicate whether the drill or performance has the objective of attaining a minimum time to do a given job. Such might be the case in learning Morse code or typing. It has little application in teaching photography. x(7) team size is self-explanatory and has no application in the example. Variables x(8) through x(10) identify special requirements for personnel of various types and for various purposes. If required, these will be an input to the cost analysis of the instructional system.

x(11) allows the course planner to specify that a particular learning event will take place in a special area. In the example, several of the learning events are coded 4, meaning that the event must take place in a small laboratory (or darkroom).

When the learning event category indicates that either drill or practice is involved, x(12) allows the course planner to specify that student mastery of the skills to be learned may be checked by calling for a *selected response*. The alternative, of course, is for the student to do more than select from among a given number of possible answers. For photography, *constructed responses*, such as operating a camera, composing a picture, or developing a film, are more typical. For classroom instruction where there is no drill or practice involved, the choice of response type is made when setting instructional strategy.

Variables x(13) and x(14) allow the course planner to specify that special equipment will be required to conduct the event and also to specify the source of the equipment. In the example, the special equipment required consists largely of cameras and related accessories; as x(14) is coded 4, the equipment will be purchased new for use in this course.

x(15) asks about the size of group that would be able to see a presentation if it were made face-to-face. If the maximum group size were less than room capacity, the presentation would have to be given more than once. To clarify this impact on scheduling further, x(16) asks how long each presentation would last. When media presentations are contemplated, x(16) also indicates what portion of the total event time is actually spent in presentation, as opposed to presentation plus discussion and other student-instructor interaction. This information helps to determine the number of minutes of film, video tape and other media software that must be prepared.

x(17) gives the course planner a chance to state that special material will be required for student performance. This is typically consumable material such as film and darkroom supplies. The answer to this question is a direct input to the system cost analysis.

x(18) indicates that all learning events specified for the example course are regularly scheduled. This does not mean that they have fixed, predetermined start and stop times—which would be inconsistent with individual variable pacing—but rather that they are encountered in regular order during the normal teaching day and are not assigned for homework.

x(19) shows whether or not student mastery of the subject matter presented in a particular learning event will be formally evaluated at some later time. Those events for which the answer is No are in most cases demonstrations or events intended to introduce the students to material that they will encounter in a subsequent performance event, probably subject to eventual formal evaluation.

x(20) states how often the subject matter presented in any learning event will be revised. In photography, revisions may result from technological developments, such as new films, new chemicals, new processes, or the like; or they may merely reflect continuing work on curriculum development. The information is stated in terms of the expected number of months between revisions and, as in the cost analysis, it is designed to show the cost of these revisions on an annual basis. A statement that there will be 48 months between revision has been interpreted to mean complete revision every 4 years, and further that 25 percent of the material will be completely revised each year. The cost of revisions relates largely to the production of new films, textbooks, workbooks, and other teaching materials.

Answering question x(20) completes part I of the curriculum analysis questionnaire. In part II, only x(21) must be answered. x(21) specifies for each learning event what class of communication media would be appropriate if in the strategy it is decided to use media. At this stage, specification is done in very general terms and is not binding in any sense. For example, code 2 merely indicates that if media were to be used, the appropriate class would be audio-still-visual.[3]

This completes the curriculum description. Other inputs, such as instructional strategy, design criteria, and institutional policy, may be varied at will by the course planner, but it is expected that the curriculum, once specified, will remain relatively fixed.

[3] For more information on media classes, see the master code list in Appendix A and Rudy Bretz, *The MODIA Questionnaire for Curriculum Analysis*, The Rand Corporation, R-1020-PR.

ANALYSIS OF STUDENT POPULATION

Although the analysis of student population can be quite complex and involve statistical analysis of prospective students' histories and the results of diagnostic tests given for the explicit purpose of considering students for a particular course, these methods have not been formalized as yet. Some crude assumptions have been made for this example.

All students entering the example course in basic photography will be Air Force enlisted personnel with similar backgrounds. They will be homogeneous in all ways except in their ability to absorb instructional material at a given rate. It has been assumed that the entire population will be normally distributed with respect to learning rate, with the distribution defined by having a mean of 1 and a standard deviation of 20 percent of the mean. In other words, the slowest students who will be in the upper tail of the time distribution (plus three standard deviations) will take 1.6 times as long as the average student to master a given set of subject matter. On the other hand, the faster students, found in the lower tail of the time distribution (minus three standard deviations), will master the given subject matter in 40 percent of the time it will take the average student. The cumulative form of this distribution will be used in conjunction with a random number generator in the student flow simulation model to assign a learning rate to each student on entry into the course.

GENERAL POLICY

General policy has been set by working through the short questionnaire described in R-1019-PR.[4] The stated policy is intended to reflect the basic policies of the Air Training Command. *Policy*, as used here, refers to the fundamental objectives of the institution. Many institutions have input-oriented objectives; some have output-oriented objectives. An input-oriented institution might be, for example, a labor union which specifies a certain number of weeks in a vocational course as a membership requirement. The Air Training Command, however, is output-oriented; if it is possible to reduce the input required for the same output, so much the better. Hence, no standard number of instructional hours of input will be required.

General policy also requires a statement of whether the school wants a standard or a diverse output. If the learners are fairly homogeneous, this question is not very important, but if they are heterogeneous, it is. The Air Training Command tries to produce standard graduates in the technical center (although no one really believes that all airmen are exactly the same when they have finished a technical course). Hence, requirements for subject matter to be mastered will be the same for all students.

Another aspect of general policy has to do with the way in which the school relates to the institutions that use its graduates and those that supply its students. In the military, students must be entered into and graduated from the course in predictable numbers and at predictable times. The easiest way to accommodate this

[4] Polly Carpenter and Barbara Horner, *The MODIA Decision Process for Developing Strategies of Air Force Instruction*, The Rand Corporation, R-1019-PR.

requirement is to present basic course content on a fixed schedule and to maintain an invariant rate of elimination or dropout of students. This, of course, makes it difficult to individualize instruction in even the limited sense of allowing each student to progress at his own rate. The Air Training Command has shown, however, that even in self-paced courses it is possible to predict graduation rates sufficiently accurately to meet the needs of the Air Force. Therefore, an aspect of the general policy stated for the example was that basic course content will not be presented on a fixed schedule.

After we had decided to use self-pacing as the basic instructional method, the following policy decisions were stated:

- Exposure to course content will not be matched to student background.
- Instructional strategies will not be matched to student learning capabilities (beyond self-pacing).
- Students will not be put into tracks (homogeneous ability groups).

INSTRUCTIONAL STRATEGY

The curriculum analysis tabulation provides a description of the course content in concise, largely quantitative form. It remains for the course planner to specify how the teaching will take place—to state his instructional strategy. This process is facilitated by providing the instructional system designer with an on-line interactive computer program to ask him the appropriate questions in the appropriate order and to guide him through the complex decision table that is inherent in the analysis of instructional strategy.[5] The computer, before asking for a decision about a particular strategy variable, refers the instructional system designer to a manual in which he finds a discussion of the important implications of each available option.

Instructional strategy is formulated in two parts by working through the decision table. The first part consists of general strategy that will govern the overall conduct of the course. First, the user refines some of the decisions he made in stating general policy. In the example, this consisted primarily of deciding to modify the general policy by using variable pacing throughout the course. This would permit better students to master course material more quickly and poorer students to take longer than the average. Thus, a limited form of adaptivity would be used. Rewards to stimulate rapid progress through the course will not be provided nor will there be any monitoring to insure that students do not waste time. Of course, learning events that are of fixed duration, such as demonstration films, will be accomplished at the same rate by all students. Upper limits will be set on the times spent taking formal evaluations, and lower limits will be set on discussion times.

Next, the planner identifies the major types of instruction that will be used in the course. The three major types of instruction relate to the requirements of the subject matter for learner performance or the use of special facilities or equipment by the learner. The simplest type of instruction (Type I) has no such requirements. If learner performance is required, but no special equipment or facilities are needed, instruction is Type II. In Type III instruction, the learner must work with special

[5] Ibid.

equipment or in special facilities to master the subject. All three types of instruction will be used in the basic photography course.

When the planner filled out the curriculum analysis, he classified each unit of instruction (learning event) by type of instruction, level of complexity, and other factors. In setting strategy he must choose an instructional method for each combination. This is the main body of the strategy-setting process. The classification scheme used to differentiate among categories of instruction for strategy-setting purposes is illustrated in Table 3. The boxes indicate all of the possible types of scheduled instruction for which separate teaching strategies may be set. Of course, not all would necessarily apply in any one course.

In the example course, for each basic instructional learning event described in the curriculum analysis, a check was entered in the appropriate box of Table 3. A strategy was set for each of the instructional categories that are indicated by strategy numbers in boxes on Table 3. This was done in the course of working through the decision table, Table 4.

The Strategy Selected for This Course

Variable pacing at the individual student level will be used.

For Types I and II instruction, formal evaluations will be given at the end of each lesson and will cover the material presented in that lesson only. Each of these quizzes will last an average of 15 minutes, or 10 percent of instructional time being evaluated, whichever is greater. There will also be a final examination that will cover all of the material presented in the course. All examinations of Type I and II instruction will be presented using the same medium that was used in the learning event being evaluated except when the original presenter was an instructor. In that case, evaluation will consist of printed questions and written answers.[6] All evaluations of Type III instruction will be conducted by a live instructor. All formal evaluations that can be conducted using selected responses from the student will be machine scored.

A formal review lasting an average of 120 minutes will take place prior to the final or end-of-course evaluation. Special instructional materials will be prepared for this review and will be presented in the same way that they were in the basic instructional events. There will be no formal reviews prior to lesson quizzes.

As a significant amount of instructional material will be presented using various forms of communication media, students will be given an opportunity to discuss this material with an instructor at prescribed intervals. These discussion sessions will take place after approximately 300 minutes of media presentation has been accumulated or at the end of each lesson but just prior to the lesson evaluation, whichever occurs first. The average length of time allocated to these discussions will be equal to 10 percent of the accumulated media presentation time since the last such discussion, but not less than 5 minutes.

The course will teach individual skills only. Type I instruction may be either relatively easy or relatively difficult, but in each case mastery of material presented will be checked using selected responses. Types II and III instruction may be either

[6] This has since been revised to permit presentation by the appropriate communication medium provided it is already on hand.

Table 3

STRATEGY POSSIBILITIES FOR SCHEDULED INSTRUCTION

Type of Response x(12)	Learning Event Type, x(5)										
		Type II Instruction					Type III Instruction				
		Performance		Demonstration		Follow-me Demo.	Performance		Demonstration		Follow-me Demo.
	Type I Instruction x(5) = 1, 2	Interactive Skills x(5) = 3	Ind. Skills x(5) = 4	Interactive Skills x(5) = 5	Ind. Skills x(5) = 6	Ind. Skills x(5) = 7	Interactive Skills x(5) = 8	Ind. Skills x(5) = 9	Interactive Skills x(5) = 10	Ind. Skills x(5) = 11	Ind. Skills x(5) = 12
Rel. Easy/Simple x(3) = 0											
Constructed x(12) = 0			--					--			
Selected x(12) = 1			--					--			
Not Specified x(12) = _	1	--		--	--		--		--	--	
Rel. Diff./Complex x(3) = 1											
Constructed x(12) = 0			3					3			
Selected x(12) = 1			2					--			
Not Specified x(12) = _	2	--			4	5	--		--	7	5

NOTE: Boxes indicate the possible instructional strategies. Numbers identify the strategies selected.

simple or complex and require that student mastery of skills taught be checked by calling for both selected and constructed responses, as dictated by the subject matter and called out in the curriculum analysis.

Relatively easy Type I instruction will be paced and presented by response-paced programs with integrated stimuli calling for selected responses from the student. The student will know when he has made the correct response by observing the reaction of the response-paced program. Provision will be made for permanent recording and machine scoring of student responses.

Relatively difficult Type I instruction will be paced by the individual student and presented by any appropriate communication medium.[7] The presentation will include integrated stimuli calling for selected responses from the student. Also included will be statements of the correct response, which will be presented to the student immediately after he has had time to respond. Students' responses will be permanently recorded and machine scored.

Complex Type II instruction calling for selected responses will be paced by the individual student and presented by any appropriate communication medium.[7] Stimuli for response will be integrated with the presentation and the student will be given knowledge of the correct response after he has had time to respond. Responses will be permanently recorded and machine scored.

Complex Type II instruction calling for constructed response will usually require that the student perform some task, such as framing good and bad compositions on a large photograph. Problems and directions will be presented by an instructor who will also set the pace for each individual student. The results of student performance will be permanently recorded either in the form of instructor's notes or what the student produces or both. Affirmation by the instructor will provide the student with on-the-spot knowledge of how well he is performing.

Type II complex pure demonstrations are presented and paced by a live instructor. As during all pure demonstrations, the student is passive.

Type II complex follow-me demonstrations of skills that call for constructed responses are presented and paced by an instructor. Students' responses will not be recorded but students will be told by the instructor whether or not they are performing correctly. As responses are not recorded, there is no need for scoring.

Complex Type III instruction calling for constructed responses will be paced and presented by an instructor. The instructor will provide problems and directions and make a running evaluation of student performance. Performance results will be permanently recorded in the form of instructors' notes or student product or both. As all responses will be constructed, machine scoring will not be possible.

Type III complex pure demonstrations will be paced by the individual student and presented by any appropriate communication medium.[8]

Type III complex follow-me demonstrations of skills calling for constructed responses are presented and paced by an instructor. Students' responses will not be recorded, but students will be told whether or not they are performing correctly by the instructor. As responses are not recorded, there is no need for scoring.

[7] In a later version, the student will be given stop and start control over a program presented by a medium other than a text, to permit individual pacing.

[8] In a later version, the student will be given stop and start control over a program presented by a medium other than a text, to permit individual pacing.

The relations between the characteristics of the learning events and the instructional strategies are displayed on Table 4. This is a decision table. The various possible combinations of the three key characteristics—x(5), instructional category, x(3), degree of difficulty of the material, and x(12), type of response—are shown above the double line as conditions or rules. The related strategy variables below the double line are the results or actions. In several cases, two or three rules call for the same action, so these have been grouped together. The last line, then, identifies six different strategies by strategy number (S). Since strategy No. 6 was later found to be identical with No. 5 at the level of detail at which we were working, they were combined. However, the strategies retain their original numbers in the table.

Table 4

RELATIONSHIP BETWEEN LEARNING EVENT CHARACTERISTICS AND BASIC INSTRUCTIONAL STRATEGY: A DECISION TABLE

Learning Event Characteristics	Possible Strategies										
Learning event category code x(5) 1 = Type I instruction (no drill or practice) 2 = Type I instruction (no drill or practice) 4 = Type II performance (ind. skills) 6 = Type II pure demonstration (ind. skills) 7 = Type II follow-me demonstration (ind. skills) 9 = Type III performance (ind. skills) 11 = Type III pure demonstration (ind. skills) 12 = Type III follow-me demonstration (ind. skills)	1	2	1	2	4	4	9	6	7	12	11
Degree of difficulty x(3) 0 = Relatively easy or simple 1 = Relatively difficult or complex	0	0	1	1	1	1	1	1	1	1	1
Acceptable type of response for Types II and III instruction x(12) 0 = Constructed response 1 = Selected response - = No response required	1	1	1	1	1	0	0	--	0	0	--
Strategy for Combination of Event Characteristics Above	**Possible Strategies**										
Pacer 2 = Individual student 3 = Instructor 4 = Response-paced program	4	4	2	2	2	3	3	3	3	3	--
Presenter 1 = Instructor 2 = Any approximate communication medium 5 = Fixed-duration program 7 = Response-paced program	7	7	2	2	2	1	1	1	1	1	5
Integrated stimuli included in presentation (1 = yes; 0 = no)	1	1	1	1	1	1	1	--	1	1	--
Constructed response required (1 = yes; 0 = no)	0[a]	0[a]	0[a]	0[a]	0	1	1	--	1	1	--
Students given immediate knowledge of correct response (1 = yes; 0 = no)	1	1	1	1	1	1	1	--	1	1	--
Student responses permanently recorded (1 = yes; 0 = no)	1	1	1	1	1	1	1	--	0	0	--
Machine scoring of selected responses (1 = yes; 0 = no)	1	1	1	1	1	0	0	--	0	0	--
Strategy number S =	1		2			3		4	5		7

[a]Note that for Type I instruction, the type of response is a strategy input, not a curriculum analysis input.

Since the computer output of the decision process is expressed in terms of sets of values of strategy variables as well as text, it will be possible, eventually, to automate the process displayed on Table 4.

Table 5 relates these six strategies to the individual learning events as they were listed in Table 2. Table 5 is thus the same as Table 2 except that an additional line has been added at the bottom containing the strategy numbers for each learning event. This is the result of applying decision Table 4 to the data characterizing each learning event. For example, take learning event 3,1 (lesson 3, event 1). Variable x(5) for this event is code 1, x(3) is 1, and x(12) is not applicable. Referring to Table 4, we note that the rule that includes these values takes strategy number 2. Therefore, code 2 has been entered on the bottom line of Table 5.

INSTRUCTIONAL SYSTEM DESIGN CRITERIA

The criteria for designing the instructional system in the example were established with a view towards imposing as few limitations on innovation as possible. The design was not to be constrained by resource limitations of any type. On the other hand, while all kinds of resources were to be considered readily available, those chosen were to be of moderate cost. The overriding criterion was the saving of student time, one of the most valuable resources. Thus, no queues would be formed as students waited for instructors or other resources to become available. Instead, all resources would be provided in sufficient quantity that no student would ever have to wait. In addition, each student would be provided with a complete set of textbooks, workbooks, and photographic supplies on entry into the course, and these items would be considered expendable.

In the general case, the next step would be to analyze local resources and constraints, because the precise configurations that would be chosen would be heavily influenced by existing facilities and resources. For example, if the school already had a closed-circuit TV system and audio-motion-visual media were needed for a particular event, it might be reasonable to use the closed-circuit system for certain teaching methods. Of course, in our example, individual, variable pacing would probably preclude such use. As we proceed, the strategy of instruction will further narrow the choices of appropriate resources.

Although the course would be given at an existing Air Force Technical School, we assumed that all resources required were to be provided new. There would be no sharing of resources or support with other courses or activities on the base. This is a somewhat unreal assumption, but served a useful purpose for the initial trial by forcing the explicit consideration of all course requirements, resulting in a maximum cost case. Subsequent analyses would be expected to relax the criteria in areas suggested by the initial analysis, in view of the special budgetary and resource availability problems of the particular base. The example provides a benchmark case, a point of departure for the consideration of other, possibly more feasible, alternatives.

Students are to enter the course in groups of ten, one group on each training day—a decision consistent with the desired output of graduates. With the course averaging two weeks in length, this entry arrangement results in an average stu-

Table 5

INSTRUCTIONAL STRATEGY KEYED TO BASIC INSTRUCTIONAL LEARNING EVENTS

Parameter	Lesson 1				Lesson 2				Lesson 3									Lesson 4						Lesson 5						
	Learning Event Number																													
	1	2	3	4	1	2	3	4	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	1	2	3	4	5	6	7
Lesson Analysis Questions																														
x(1) Learning event time (minutes)[a]	35	120	120	75	30	120	30	150	35	60	30	30	60	60	120	45	340	15	30	30	15	60	60	90	30	30	30	30	60	180
x(2) Housekeeping time (minutes)[a]	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
x(3) Interrelated concepts or skills	0	0	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1
x(4) Type of special learning event	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
x(5) Learning event category code	1	1	11	2	2	2	11	9	1	1	1	11	1	1	12	2	9	1	7	11	1	9	9	1	11	4	6	4	4	9
x(6) Minimum performance rate an objective	--	--	--	--	--	--	--	0	--	--	--	--	--	--	0	--	0	--	1	--	--	0	0	--	--	0	--	0	0	0
x(7) Team size	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Additional support personnel required:																														
x(8) Instructor level	--	--	0	0	0	0	0	--	--	--	--	0	--	--	--	0	--	--	--	0	--	--	--	--	0	--	0	--	--	--
x(8) Student assistant level	--	--	0	0	0	0	0	--	--	--	--	0	--	--	--	0	--	--	--	0	--	--	--	--	0	--	--	--	--	--
x(9) Instructor required for knowledge of correct responses	--	--	--	--	--	--	--	1	--	--	--	--	--	--	1	--	1	--	1	--	--	1	1	--	--	1	--	0	1	0
x(10) Supervision required for safety	--	--	--	--	--	--	--	1	--	--	--	--	--	--	1	--	1	--	--	--	--	1	1	--	--	--	--	--	--	3
x(11) Special area required to produce presentation	--	--	4	0	0	0	0	2	--	--	--	2	--	--	2	0	2	--	--	4	--	4	4	--	2	--	--	--	--	2
x(12) Selected responses satisfactory for evaluation	--	--	--	--	--	--	--	0	--	--	--	--	--	--	0	--	0	--	--	--	--	0	0	--	--	1	--	0	0	0
x(13) Special equipment required to produce presentation	--	--	1	1	1	1	1	1	--	--	--	1	--	--	1	1	1	--	--	1	--	1	1	--	1	--	--	--	--	--
x(14) Source of special equipment if required	--	--	4	4	4	4	4	4	--	--	--	4	--	--	4	4	4	--	--	4	--	4	4	--	4	--	--	--	--	--

Table 5--continued

x(15) Number of viewers who can see one face-to-face presentation	50	50	10	50	50	50	10	--	50	50	50	10	50	50	5	5	--	50	50	10	50	--	--	50	5	--	5	--	--	--
x(16) Length of one presentation, demonstration, or presentation of problems and directions in minutes	25	60	90	50	20	100	30	10	30	50	25	25	50	50	30	35	10	15	20	25	15	5	5	75	20	--	15	5	0	10
x(17) Special materials required for performance	--	--	--	--	--	--	--	1	--	--	--	--	--	--	1	--	1	--	1	--	--	1	1	--	--	0	--	1	0	--
x(18) Learning event regularly scheduled	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
x(19) Subject matter to be formally evaluated	0	1	0	1	0	1	0	1	1	1	1	0	1	1	1	1	1	0	1	0	1	1	1	1	0	0	0	1	0	0
x(20) Months between revision of curriculum content	12	24	60	60	60	60	48	48	12	60	60	60	24	60	48	48	60	48	48	60	36	48	48	60	60	60	60	60	60	60
x(21) Appropriate media class	2	5	1	5	5	5	4	5	5	5	5	5	2	5	5	5	5	5	4	4	5	5	5	5	5	5	1	5	0	5
Strategy number	1	1	7	1	1	1	7	3	2	2	2	7	2	2	5	2	3	1	5	7	2	3	3	2	7	2	4	3	3	3

[a]In this example, learning event time x(1) includes housekeeping time x(2).

dent load of 100 students and—assuming no dropouts—an annual graduate output of 2,600 students.

All standard facilities, equipment, and services normally provided to staff and students of Air Force Technical Training courses were to be provided to the staff and students of the example course. School facilities would be open and available to all students five days a week and the course would run five hours a day[9] between 9:00 a.m. and 4:00 p.m., except for holidays, of which there will be ten per year.

[9] Seven hours less one hour for lunch and ten minutes break time each hour ($7 - 2 = 5$).

III. DESIGNING THE INSTRUCTIONAL SYSTEM

At this point, the necessary inputs have been specified and the system design process can begin. Several steps are involved. First, the requirements for special teaching facilities are spelled out, and the media system characteristics for the basic learning events are firmed up. Because they are so interrelated, these two problems are dealt with simultaneously.

Finally, the flow of students through the course is simulated, to estimate the demands for space in each type of special teaching facility, for sets of media hardware and software, and for instructors. This completes the system design process and provides the essential inputs for an analysis of the cost of the system.

MEDIA SYSTEM CHARACTERISTICS AND SPECIAL TEACHING FACILITIES

Specifying each of these requires a general description of the physical characteristics of the proposed plant and of the modus operandi of the course. In the real world, the physical characteristics of the plant specified would be strongly influenced by the existing facilities available for use. In the example, these have been prescribed exclusively to fit the need.

Two features of the example course drive the selection of media and teaching facilities: the decisions that students (1) are to be individually and thus variably paced and (2) are not to wait for required resources. To achieve this, all resources have to be provided in sufficient quantity to meet peak demands. With an average student load of 100, a substantial demand for resources seemed indicated; hence, an underlying objective was to design a system that would nevertheless result in a reasonable cost.

Strategy calls for the use of instructors in several learning events. In the usual system, several (or many) students meet with one instructor. However, the decision to allow each student to proceed at his own pace and to tolerate no queues made the usual class arrangement unworkable. Thus, instructors had to be used on a tutorial basis: any student needing an instructor had one available to him on demand. This was another indication of a potentially expensive system and provided additional motivation for the use of media where appropriate.

When the needed methodological research is completed, it may be possible that much of the system design process can be embodied in a rather formal set of decision rules. These can, of course, be automated. At present, however, the rules are little more than suggested. For this reason, we present only one fully worked out example here, although, when MODIA is completed, a number of alternative system designs should be fully formulated before one is chosen.

While working out the example, we came to realize that the process of thinking through the problem provides the planner with valuable insights that may well justify the time required. Rather than complete automation, perhaps it would be most useful to provide the planner with aids, such as decision tables, that make his task easier, without removing him from the process.

In the example case, one of the alternatives considered was computer-assisted instruction. This was discarded primarily on the basis of an intuitive feeling that CAI would be underutilized, and hence overly expensive, in a course where so much live instructor contact was prescribed. (In a real-world situation, such decisions would be heavily influenced by the possibilities of sharing such resources among several courses.)

Multimedia carrels were also considered and rejected on a similar basis: the cost would seem too great for the utilization. Although minimum cost was not stated as a design criterion, it prevailed where no other considerations dictated the choice.

Another possibility was the use of one media system by a group, as, for example, having a group of students view a film together. This idea was discarded because it conflicted with the requirements for individual pacing and no queuing.

Designing the Facilities

We knew that the facilities required would be strongly influenced by the media selected. Because of the use of individual pacing, we felt that self-contained portable, rather than fixed, media hardware would be most appropriate. Having established that such media were available at reasonable cost, we designed a central storage place where students could check the hardware and material in and out, on demand.

The possibility of students taking the equipment and software to use wherever they might choose was considered, but eliminated because of the difficulty of controlling and maintaining the media systems. Instead, there would be a general-purpose carrel area adjacent to the media storage—a room equipped with only chairs and carrels, each with desk and shelf space and an electric power supply. Students would check out hardware and software appropriate to the learning event they were entering, take the material to an available carrel to use, and return the items at the completion of the learning event or at the end of the learning day. A clerk/monitor responsible for issuing and receiving materials would be present at all times during the learning day.

For learning events requiring the use of darkrooms, enough fully equipped individual darkrooms to meet peak demands were specified, each large enough to accommodate one student, and perhaps an instructor too.

Facilities for meeting with instructors were originally conceived as being separate tutorial rooms and discussion rooms. Tutorial rooms would be individual cubicles just large enough to hold a desk, a table, two chairs, and the aids and devices required for instruction. Discussion rooms would be the same without the instructional aids and devices. Any examinations given in person by instructors would be held in the tutorial rooms. It was assumed that examinations requiring the use of media would take place in the general carrel facility, and that pencil-and-paper tests would be held in a separate area, supervised by a monitor who would provide the materials, on request, and collect the results. When the initial formulation was completed, we realized that there was no need for separate discussion rooms or a special examination room; money would be saved by holding discussions in the tutorial rooms and giving written examinations in the carrel room.

To these space requirements must be added supporting facilities, such as offices for instructors and course supervisors, and shop space for maintenance of media hardware and software. These facilities are included in estimating the total costs, and are set forth in detail in Appendix B.

Finally, since a significant part of the course requires taking pictures out of doors, the outdoors is another teaching facility.

Selecting Specific Media Systems

We have already decided that media systems—consisting of an item of hardware and one or more associated items of software—are to be portable and self-contained (and, by inference, simple and sturdy enough for students to operate independently). The next step is to define the essential characteristics of each of the media systems required, and, finally, to specify in concrete terms a representative item on which to base a cost estimate. The required characteristics follow logically from a combination of the earlier curriculum analysis and instructional strategy decisions. Here we build upon the characteristics defined in Table 5, which is reproduced as the top section of Table 6.

Although the formal decision rules have not yet been defined, we present here a step toward their formalization.

The general characteristics of the media systems required are indicated by the variables M(1) through M(9), in the lower section of Table 6. The variable H reflects the code for the representative item of media hardware that will be purchased; P is the type of facility that will be required to produce the software. In this example, all software will be provided from outside sources on a contract purchase basis. The variable L associates a teaching location or facility with each basic instructional event in the curriculum analysis. All the possible codes for M, H, P, and L are presented in the master code list, Appendix A.

As an example of how the media system characteristics were arrived at, consider the results for learning event 1 in lesson 1. M(1) indicates the choice of a medium for presenting instructional materials. The curriculum analysis variable x(21) states that if media are to be used, class II (audio-still-visual) is the most appropriate. Strategy variable 6[10] prescribes that the presentation will be made by a response-paced program, which implies that a communication medium *will* be used. Audio-still-visual can be obtained in several ways. Still-picture television is one possibility, sound filmstrip is another, sound-slide set is still another. Television seemed inappropriate on the grounds of portability and cost, so the choice was between the sound filmstrip and the sound-slide set. The relative ease with which

[10] Strategy variables shown in Table 6 are defined in the master code list, Appendix A.

Table 6

SUMMARY OF BASIC INSTRUCTIONAL LEARNING EVENTS--STRATEGY AND MEDI., INFORMATION

Parameter	Lesson 1				Lesson 2				Lesson 3									Lesson 4						Lesson 5						
	Learning Event Number																													
	1	2	3	4	1	2	3	4	1	2	3	4	5	6	7	8	9	1	2	3	4	5	6	1	2	3	4	5	6	7
Curriculum Analysis																														
x(1) Learning event time (minutes)[a]	35	120	120	75	30	120	30	150	35	60	30	30	60	60	120	45	340	15	30	30	15	60	60	90	30	30	30	30	60	180
x(2) Housekeeping time (minutes)[a]	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
x(3) Interrelated concepts or skills	0	0	1	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1
x(4) Type of special learning event	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
x(5) Learning event category code	1	1	11	2	2	2	11	9	1	1	1	11	1	1	12	2	9	1	7	11	1	9	9	1	11	4	6	4	4	9
x(6) Minimum performance rate an objective	--	--	--	--	--	--	--	0	--	--	--	--	--	--	0	--	0	--	1	--	--	0	0	--	--	0	--	0	0	0
x(7) Team size	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Additional support personnel required:																														
x(8) Instructor level	--	--	0	0	0	0	0	--	--	--	--	0	--	--	--	0	--	--	--	0	--	--	--	--	0	--	0	--	--	--
x(8) Student assistant level	--	--	0	0	0	0	0	--	--	--	--	0	--	--	--	0	--	--	--	0	--	--	--	--	0	--	--	--	--	--
x(9) Instructor required for knowledge of correct responses	--	--	--	--	--	--	--	1	--	--	--	--	--	--	1	--	1	--	1	--	--	1	1	--	--	1	--	0	1	0
x(10) Supervision required for safety	--	--	--	--	--	--	--	1	--	--	--	--	--	--	1	--	1	--	--	--	--	1	1	--	--	--	--	--	--	3
x(11) Special area required to produce presentation	--	--	4	0	0	0	0	2	--	--	--	2	--	--	2	0	2	--	--	4	--	4	4	--	2	--	--	--	--	2
x(12) Selected responses satisfactory for evaluation	--	--	--	--	--	--	--	0	--	--	--	--	--	--	0	--	0	--	--	--	--	0	0	--	--	1	--	0	0	0
x(13) Special equipment required to produce presentation	--	--	1	1	1	1	1	1	--	--	--	1	--	--	1	1	1	--	--	1	--	1	1	--	1	--	--	--	--	--
x(14) Source of special equipment if required	--	--	4	4	4	4	4	4	--	--	--	4	--	--	4	4	4	--	--	4	--	4	4	--	4	--	--	--	--	--

Table 6--continued

x(15) Number of viewers who can see one face-to-face presentation	50	50	10	50	50	50	10	--	50	50	50	10	50	50	5	5	--	50	50	10	50	--	--	50	5	--	5	--	--	--
x(16) Length of one presentation, demonstration, or presentation of problems and directions in minutes	25	60	90	50	20	100	30	10	30	50	25	25	50	50	30	35	10	15	20	25	15	5	5	75	20	--	15	5	0	10
x(17) Special materials required for performance	--	--	--	--	--	--	--	1	--	--	--	--	--	--	1	--	1	--	1	--	--	1	1	--	--	0	--	1	0	--
x(18) Learning event regularly scheduled	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
x(19) Subject matter to be formally evaluated	0	1	0	1	0	1	0	1	1	1	1	0	1	1	1	1	1	0	1	0	1	1	1	1	0	0	0	1	0	0
x(20) Months between revision of curriculum content	12	24	60	50	60	60	48	48	12	60	60	60	24	60	48	48	60	48	48	60	36	48	48	60	60	60	60	60	60	60
x(21) Appropriate media class	2	5	1	5	5	5	4	5	5	5	5	5	2	5	5	5	5	5	4	4	5	5	5	5	5	5	1	5	0	5
Basic Instructional Strategy[b]																														
S Strategy number	1	1	7	1	1	1	7	3	2	2	2	7	2	2	5	2	3	1	5	7	2	3	3	2	7	2	4	3	3	3
(14) Pacer	4	4	--	4	4	4	--	3	2	2	2	--	2	2	3	2	3	4	3	--	2	3	3	2	--	2	3	3	3	3
(6) Presenter	7	7	5	7	7	7	5	1	2	2	2	5	2	2	1	2	1	7	1	5	2	1	1	2	5	2	1	1	1	1
(7) Integrated stimuli included in presentation	1	1	--	1	1	1	--	1	1	1	1	--	1	1	1	1	1	1	1	--	1	1	1	1	--	1	--	1	1	1
(9) Constructed response required	0	0	--	0	0	0	--	1	0	0	0	--	0	0	1	0	1	0	1	--	0	1	1	0	--	0	--	1	1	1
(29) Students given immediate knowledge of correct response	1	1	--	1	1	1	--	1	1	1	1	--	1	1	1	1	1	1	1	--	1	1	1	1	--	1	--	1	1	1
(8) Student responses recorded	1	1	--	1	1	1	--	1	1	1	1	--	1	1	0	1	1	1	0	--	1	1	1	1	--	1	--	1	1	1
(10) Machine scoring of selected response	1	1	--	1	1	1	--	0	1	1	1	--	1	1	0	1	0	1	0	--	1	0	0	1	--	1	--	0	0	0
Media System Characteristics, Teaching, and Production Locations																														
M(1) Presentation medium	4	5	1	5	5	5	2	0	6	6	6	8	4	6	0	6	0	5	0	2	6	0	0	6	8	6	0	0	0	0

(Continued)

Table 6--continued

M(2)	Pacer of presentation	1	1	4	1	1	1	2	3	2	2	2	2	2	2	3	2	3	1	3	2	2	3	3	2	2	2	3	3	3	3
M(3)	Internal random access required	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M(4)	Pacing control device	1	2	--	2	2	2	4	--	--	--	--	--	4	--	--	--	--	2	--	4	--	--	--	--	--	--	--	--	--	--
M(5)	Source of immediate knowledge of results	1	1	--	1	1	1	--	3	2	2	2	--	2	2	3	2	3	1	3	--	2	3	3	2	--	2	3	3	3	3
M(6)	Permanent recording method	4	4	--	4	4	4	--	2	5	5	5	--	5	5	0	5	2	4	0	--	5	2	2	5	--	5	--	2	2	2
M(7)	Portable media hardware required	1	1	1	1	1	1	1	--	--	--	--	--	1	--	--	--	--	1	--	1	--	--	--	--	--	--	--	--	--	--
M(8)	Instructor provided with guide	--	--	--	--	--	--	--	1	--	--	--	--	--	--	1	--	0	--	--	--	--	--	--	--	--	--	--	--	--	--
M(9)	Method of machine scoring selected responses	2	2	--	2	2	2	--	--	1	1	1	--	1	1	--	1	--	2	--	--	1	--	--	1	--	1	--	--	--	--
L	Teaching location	5	5	5	5	5	5	5	2	5	5	5	5	5	5	2	5	2	5	0	5	5	4	4	5	5	5	2	0	0	2
P	Location of software production	2	2	3	2	2	2	3	1	1	1	1	1	2	1	1	1	--	2	--	3	1	--	--	1	1	3	--	--	--	--
H	[illegible]	7	8	3	8	8	8	6	9	--	--	--	--	7	--	9	--	9	8	9	6	--	9	9	--	--	--	9	9	9	9

[a]In this example, learning event time x(1) includes housekeeping time x(2).

[b]Strategy variables are given in Appendix A the Master Code List.

the sound-slide set can be revised led to its selection. In other respects, there was little choice between the two. M(1), presentation medium, was set equal to 4, the code for sound-slide set.

M(2) requires a statement of how the pacing of the presentation will be accomplished. This has implications for media hardware and for software. In this case, strategy variable 14 indicates that the presentation will be by a response-paced program. From the hardware point of view, this means that a response selection and control component will have to be included in the total package. With a response-paced presentation, stimuli for overt student responses are integrated into the presentation, and, having solicited a response, the presentation medium will not move ahead until a correct response has been registered. Responses will of course be selected from multiple choices and can be communicated in a wide variety of ways. A multiple-key keyboard is one possibility. Making contact with a stylus through a prepunched stencil is another. Setting M(2) equal to 1 indicates only that the presentation will be paced by the students' correct responses.

M(3) permits specifying a requirement for the student to have internal random access to the material being presented. This means that he may proceed at his own rate, skipping certain material, going back over other material, and so on. From the hardware design point of view, the place where this consideration is most important, having internal random access requires that appropriate stop/start, fast forward, fast reverse, stop motion, and recycle controls be an integral part of the package. For this event, however, response pacing precludes the possibility of internal random access, so M(3) is set equal to zero.

M(4), the pacing control device, follows from M(1) and M(2), and further specifies the nature of the control device that will allow student responses to pace the presentation. M(1) called for the presentation to be made with a sound-slide set; the portable hardware requirement means that a portable sound-slide set projector will be used. It seemed reasonable that the response control device need not be a feature built into the projector, but rather one that could be attached when required. In this way the same projector could be used in other than the response-paced mode (as it is in learning event 5 of lesson 3, where the projector is paced by the student's judgment). Therefore, M(4) was set equal to 1, the code for separate response selection device for response pacing of projectors, viewers, etc.

Strategy variable 29 tells us that the student will be given knowledge of the correct response to stimuli immediately after he has had a chance to respond. M(5) is set to indicate how this will be accomplished. The essence of a response-paced device is that, once it has asked for a response, it will not move ahead until the correct response has been made. In this way, the behavior of the program itself indicates to the student whether he has responded correctly or incorrectly. To be sure, if he responds incorrectly the medium will not tell him what the correct response should have been. In that sense, he is not provided with that knowledge immediately after he has had a chance to respond. However, the reaction of the projector or viewer is assumed to provide the necessary feedback, and M(5) is set equal to 1.

Strategy variable 8 indicates that student responses shall be permanently recorded, presumably for analysis and evaluation at some later date. When a response-paced program is used, no student will complete the event without answering all questions correctly (unless an arbitrary time limit is imposed, which would be inconsistent with the notion of allowing each student to set his own pace). Therefore, the mere number of correct responses is not a useful datum. It could be useful, however, to record the length of time the student spends in the event. A simple clock-in, clock-out system could accomplish this. The results of such a system could be misleading, as one student might spend considerable time thinking before responding and another student might try each answer until he gets the right one. However, the information could indicate which events were more or less difficult.

The most useful information would be a record of the total responses made to each question, both right and wrong. This latter seemed to be the preferred choice, even though other possibilities surely exist. It was assumed that the required counter could be incorporated into the response control device. The permanent record might result from monitoring the counter or possibly even having a printout of the desired totals prepared automatically by the device itself. The results would be turned in on completion of the event and maintained in a student file. M(6), permanent recording method, was set equal to 4, the code for records kept by response selection device.

M(7) provides an opportunity to specify whether or not portable media hardware are required. The rationale for answering this question Yes has already been discussed. M(7) was therefore set equal to 1. M(8) applies only when the presentation of instructional material is made by a live instructor and, consequently, is not answered for this event.

Strategy variable 10 calls for student responses to be machine scored. The ramifications of this have already been discussed with respect to M(6) and need not be discussed again. It has been assumed that, whatever the nature of the score decided upon, it will be provided by a counter or a similar mechanism incorporated in the response-control device. M(9) is set equal to 2.

Since the appropriate location is the general carrel area, the location code L is set equal to 5.

The next requirement is to specify generally the type of facility required to produce the relevant software—in this case, the slides and the related audio tape. This information will be used to estimate the software costs, which will be described ter. It is necessary to refer to the subject matter called out in the curriculum description. This event is introductory in nature and includes an overview of the course, a statement of the administrative and procedural practices to be followed, and so on. No requirement for elaborate visuals requiring filming on location or even out of doors is indicated. Rather, it is supposed that all of the material required can be produced in a small studio, a workroom, or both. To indicate this, the variable P is set equal to 2.

Drawing on the information first specified by the variable M, a media hardware system whose cost can be estimated is next identified. The necessary characteristics are used in logical fashion to choose among a wide range of possibilities. Obviously there are many different, currently available projectors that could be selected and equally many response control devices and scoring devices. Modification of currently available equipment and even completely new designs can be envisaged. However, our primary objective here is to obtain an estimate of the cost of the entire instructional system, rather than to be precise about the cost of a single item of equipment. With this in mind, a typical or representative item was selected and described: a portable Super 8 sound-slide set projector and audio cassette system for use with a response selection and control device. To indicate this, hardware code H was set equal to 7. At this stage of the analysis, choosing a least-cost item was not attempted. That issue, however, may prove worthy of addressing after viewing the total instructional system cost.

Media system characteristics, teaching location, production area, and media hardware packages are specified for each learning event.

ANALYZING USE OF INSTRUCTORS

There are some slight differences in procedure when the presentation must be made by an instructor. Looking briefly at the process used for learning event 4 of lesson 2 will point up some of these.

The specification of M(1), presentation medium, and M(2), the pacer of the presentation, is straightforward. They are each the instructor. Hence, M(1) equals 0 and M(2) equals 3. Internal random access, if it were required, would be achieved, quite simply, through student interaction with the instructor. However, it is not required here, and M(3) is set equal to zero. A pacing control device is also irrelevant where the pacer is a live instructor, so M(4) is not specified at all. Strategy variable 29 does state that students will be given knowledge of correct results immediately after they have been asked and had a chance to respond. With the instructor providing the stimuli and observing the students' performance, his affirmation or demonstration of how it should have been done will meet the requirement. M(5) is set equal to 3 to indicate that this is the case.

Strategy also calls for student responses to be permanently recorded. With the instructor present, this can be accomplished in a number of ways: recording on film, on video tape, on audio tape or disk, and so on. Another possibility is for the instructor to keep a set of formal notes on his evaluation of the student's performance. In some instances, for example when a student performs by producing a product, the product itself will provide a sufficient record. For this event it has been specified that one or both of the latter will be used. M(6) has been set equal to 2 to indicate this choice, instructor's notes and/or student product.

With an instructor and no media, media hardware portability is irrelevant, so M(7) is left blank.

In certain instances, when the instructor is both the presenter and the pacer, strategy may specify that he be provided with a programmed guide. Such a guide would prescribe the order of presentation of subject matter and also incorporate stimuli for student response at appropriate places in the presentation. A step down from this would be to provide the instructor with a lesson guide that would give him information only on the substance and suggested order of presentation. A third possibility obviously is to leave him completely on his own and provide him with nothing but a general statement of the subject matter to be covered. The choice would probably depend on the instructor's ability to adapt to student needs on the spot and on the degree to which a standardized treatment of the subject matter is desired. In the example course, the strategy calls for a lesson guide to be provided, so M(8) is set equal to 1.

Strategy variable 9 calls for students to respond to performance stimuli by making constructed responses. It is assumed that it is not feasible to machine score constructed responses, so M(9) is also an inappropriate question and the answer is not filled in.

Curriculum analysis variable x(11) is 2, which means that the learning event must take place out of doors but near the school. The students will either be taking pictures or performing a process incidental to taking pictures. The fact that x(11) is 2 leads to the teaching location code L being set equal to 2 also.

The only software to be produced for this event is the lesson guide, and a print shop or reproduction center is all that is required. P is therefore set equal to 1.

For computing purposes, an instructor is distinguished from a piece of media hardware by setting the hardware code, H, equal to 9, as in this learning event.

Table 7 shows a simplified version of the decision criteria for specifying the values of H for all learning events. At this stage of our research, this table should be regarded as an indicator of the need for a better one, more than anything else. However, the values shown for H in Table 6 are consistent with the rules shown in Table 7.

Table 7

SELECTION OF HARDWARE OR INSTRUCTOR FOR BASIC INSTRUCTIONAL LEARNING EVENTS

Item	Code	Combinations Found in Example				
Presentation medium	M(1)	0	1	2	4	5
Pacer of presentation	M(2)	3	4	2	2	1
Pacing control device	M(4)					2
Hardware or instructor	H	9	3	6	7	8

M(1) = 0: Instructor
M(1) = 1: Sound film (motion)
M(1) = 2: Silent film (motion)
M(1) = 4: Slide set (sound)
M(1) = 5: Class V teaching machine

M(2) = 1: Student's correct responses
M(2) = 2: Student's judgment
M(2) = 3: Instructor
M(2) = 4: Fixed-duration program

H = 3: Portable Super 8 sound-motion film viewer with on-off control only
H = 6: Portable Super 8 silent-motion film viewer with on-off control only
H = 7: Portable Super 8 sound-slide set projector with on-off control only
H = 8: Portable class V teaching machine with response selection component
H = 9: Live instructor

PLANNING REVIEWS, EXAMINATIONS, AND DISCUSSIONS

The next step in the design process is to flesh out the curriculum analysis by introducing planned reviews, formal examinations, and scheduled discussions, and to derive the implications of each for media systems and facilities. This was done for the example as follows.

The strategy adopted calls for end-of-lesson and end-of-course examinations. Lesson quizzes will last, on the average, 15 minutes or 10 percent of the instructional time being evaluated, whichever is greater. The final exam will last, on the average, 360 minutes.

All formal examinations for Type I and II instruction are to be presented using the same medium that was used in the learning event being evaluated, unless the original presenter was an instructor. In that case, the examination will use printed materials. All examinations of Type III instruction will be conducted by an instructor. All examinations calling for selected responses will be machine scored.

These strategy rules were applied to the learning events that will be subject to formal examination, as indicated by curriculum analysis variable x(19). This provided the conditions in the first three lines of the decision table shown as Table 8. Along with the appropriate media class (entered where the presenter was not an instructor) and the location (entered for Type III instruction), they lead to the actions shown as characteristics of examination events.

Table 8

DECISION TABLE FOR EXAMINATION EVENTS

Characteristics of Instructional Events[a]	Possible Alternatives[b]				
Type I or II instruction [x(5) = 1 - 7]	Y	Y	Y	N	N
Presentation by live instructor [M(1) = 0]	Y	N	N	--	--
Selected responses appropriate [x(12) = 1 or __(9) = 0]	N	Y	Y	N	N
Appropriate media class x(21)	--	2	5	--	--
Location L	--	--	--	2	4
Characteristics of Examination Events[a]	**Possible Alternatives[b]**				
Selected response appropriate [x(12) = 1 or M(9) = 0]	N	Y	Y	N	N
Presenter of problems and directions M(1)	7	4	7	0	0
Pacer of examination M(2)	2	2	2	3	3
Method of recording results M(6)	3	5	5	2	2
Portable hardware required [M(7) = 1]	--	Y	--	--	--
Instructor has guide M(8)	--	--	--	3	3
Method of machine scoring M(9)	--	1	1	--	--
Location of examination L	7	5	7	2	4
Location of software production P	1	2	1	1	1
Media hardware/instructor H	--	7	--	9	9

[a]See Master Code List for meanings of variable values.

[b]As they appear in the example course.

We shall now discuss these actions line by line. The first, whether selected response is appropriate, is a direct consequence of the characteristic of the instructional event, line 3, above. The second, presenter of problems and directions, comes directly from the strategy stated above. The presenter is, therefore, a set of written questions [M(1)=7] if the original presenter was an instructor [M(1)=0] or if the learning event was presented by a still-visual medium [x(21)=5]; a sound-slide set [M(1)=4] if the learning event was presented by an audio-still-visual medium [x(21) =2]; and an instructor [M(1)=0] if the learning event was Type III instruction [x(5) ≠1-7].

The pacer of the examination will be the student [M(2)=2] if the examination is presented by a medium [M(1)-4 or 7], or the instructor [M(2)=3] if the examination is presented by an instructor [M(1)=0]. In a more general case, the possibility of using a programmed test with branching should be considered. For the example, simpler testing means were chosen.

The methods of recording results were also kept simple: The students were to write in their workbooks [M(6)=3] if the examination involved Type I or II instruction and constructed responses were called for; they would use a mark-sense form [M(6)=5] if selected responses were called for; and a student product would be the record [M(6)=2] if Type III instruction were involved.

The requirement for portability of hardware was relevant only where hardware would be used for presentation [M(1)=4]. Since sound-slide sets would already be available for use in the general carrel area, this is answered Yes. Similarly, a guide is needed by the instructor [M(8)=3] only when he is giving the examination. Machine scoring is relevant only when selected responses are called for. Since mark-sense was chosen as the means of recording, M(9)=1.

For Type III instruction, the examination is given in the same location as the original learning event. For Type I or II, it is given in the paper-and-pencil testing area (L=7) if the examination is presented by the printed page [M(1)=7] and in the general carrel area (L=5) if the sound-slide set is used [M(1)=4]. The location of software production is the print shop (P=1) if printed tests or guides are used. A small studio or workroom will be needed to produce the sound-slide set (P=2). For the sound-slide set, a portable Super 8 sound-slide set projector and studio cassette system will be needed (H=7). The printed page needs no hardware. Otherwise, H =9 (the "hardware" is an instructor).

Planning Quizzes and Final Examinations

The strategy calls for each lesson quiz to cover material presented in that lesson only, and for the final exam to cover the entire course. Therefore, each lesson quiz could be derived from the learning events in that lesson and the final exam could be derived by combining the lesson quizzes. These steps were accomplished as follows.

The characteristics of the instructional events to be formally evaluated were organized by lesson and learning event number; within each lesson they were combined when all relevant characteristics but average time, x(1), were the same. The average times were added to give a total average instructional time for the combined events. This process was continued until each combination of events to be evaluated within a lesson was unique in all relevant characteristics.

An evaluation event was created for each of these unique instructional events. The times assigned to the evaluation events result from a proration of the total evaluation time required, based on the proportion of instructional time per unique instructional event to total time for all instructional events to be evaluated. The strategy shown in Table 9 and the descriptors of the learning events lead to the descriptions shown in Table 8. The ordering of the events within the quizzes for each lesson is completely arbitrary (except that the quizzes come at the end of the lesson).

Continuing to combine instructional events subject to evaluation by the same methods, this time for all lessons, resulted in a set of unique instructional events for the final examination.

Considerable research remains to be done on the development of formal examinations, the exact content of examination events, and the order in which subject matter is evaluated. At this juncture, no explicit treatment of these matters has been given.

The examination events constructed as just described are shown in Table 9, along with events for discussions and reviews. The strategy specifies that there will be a formal review lasting 120 minutes prior to the final exam and that, as with the exam, this review will be conducted in exactly the same way as will the learning events being reviewed. Thus, instead of deriving the required descriptors from the decision table used for examination events, they were taken directly from the relevant instructional events themselves. On the other hand, the procedure for combining instructional events and calculating the time for the event was exactly the same as for the end-of-course evaluation. As above, the ordering is arbitrary. Note that the end-of-course review and the final exam have been coded as though they were the equivalent of additional lessons.

Planning Discussion Time

According to the strategy, an opportunity is to be provided for each student to discuss with an instructor the instructional material presented by media at the end of each lesson, prior to formal evaluation of that lesson, or after the accumulation of 300 minutes of such time. The time allotted to each discussion was to be equal, on the average, to 10 percent of the accumulated media time, but not less than 5 minutes.

Presentation medium code M(1) (see Table 6) indicates which events use media and, hence—along with x(1), average presentation time—is the key to when discussion events should be introduced and to their length. A slight relaxation of the rule was required in one instance, so that all discussions, for this example, could be inserted at the end of lessons. All were scheduled to last 10 percent of accumulated media presentation time.

The descriptors for all discussions are identical, with the exception of lesson and learning event number. They are: average time x(1); learning event category code x(5)—in this case x(5)=D; whether the learning event is regularly scheduled [x(18)=1]; the appropriate media class [x(21)=0]; presentation by instructor [M(1)=0]; teaching location in discussion room (L=6); and an instructor for "hardware" (H=9).

The combined information shown in Tables 6 and 9 constitutes the complete quantitative description of the example course in basic photography.

Table 9

COURSE DESCRIPTION: DISCUSSION, REVIEW, AND EXAMINATION EVENTS

Parameter	Lesson 1		Lesson 2			Lesson 3				Lesson 4				Lesson 5			Lesson 6					Lesson 7				
	Learning Event Number																									
	5	6	5	6	7	10	11	12	13	7	8	9	10	8	9	10	1	2	3	4	5	1	2	3	4	5
Curriculum Analysis																										
x(1) Learning event time (minutes)	35	20	18	12	15	32	23	6	36	10	3	2	12	15	11	4	27	25	49	12	7	169	18	15	128	30
x(3) Interrelated concepts or skills	--	0	--	0	1	--	1	1	1	--	1	1	1	--	1	1	1	0	1	1	1	1	1	1	1	1
x(5)[a] Learning event category code	D	E	D	E	E	D	E	E	E	D	E	E	E	D	E	E	R	R	R	R	R	E	E	E	E	E
x(13) Special equipment required to produce presentation	--	1	--	1	1	--	1	--	1	--	1	--	1	--	--	--	1	1	1	[illegible]	--	1	1	--	1	1
x(14) Source of special equipment if required	--	4	--	4	4	--	4	--	4	--	4	--	4	--	--	--	4	4	4	4	--	4	4	--	4	4
x(17) Special materials required for performance	--	--	--	--	1	--	--	--	1	--	1	--	1	--	--	1	--	--	1	1	1	--	1	--	1	1
x(18) Learning event regularly scheduled	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
x(20) Months between revision of curriculum content	--	24	--	60	48	--	12	24	48	--	48	36	48	--	60	60	12	24	48	48	60	12	48	[illegible]	48	48
x(21) Appropriate media class	0	5	0	5	5	0	5	2	5	0	4	5	5	0	5	5	5	5	5	5	5	5	5	2	5	5
Basic Instructional Strategy																										
(9) Constructed response required	--	0	--	0	1	--	0	1	1	--	1	0	1	--	0	1	0	0	1	1	[illegible]	0	1	1	1	1
Media System Characteristics, Teaching, and Production Locations																										
M(1) Presentation medium	0	7	0	7	0	0	7	4	0	0	7	7	0	0	7	7	6	5	0	0	0	7	7	4	0	0

Table 9--continued

M(2)	Pacer of presentation	--	2	--	2	3	--	2	2	3	--	2	2	3	--	2	2	2	1	3	3	3	2	2	2	3	3
M(3)	Internal random access required	--	--	.	--	--	--	--	--	--	--	--	--	--	--	--	--	0	0	0	0	0	--	--	--	--	--
M(4)	Pacing control device	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2	--	--	--	--	--	--	--	--
M(5)	Source of immediate knowledge of results	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2	1	3	3	3	--	--	--	--	--
M(6)	Permanent recording method	--	5	--	5	2	--	5	5	2	--	3	5	2	--	5	3	5	4	2	2	2	5	3	5	2	2
M(7)	Portable media hardware required	--	--	--	--	--	--	--	1	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	1	--	--
M(8)	Instructor provided with guide	--	--	--	--	3	--	--	--	3	--	--	--	3	--	--	--	--	--	1	--	--	--	--	--	3	3
M(9)	Method of machine scoring selected responses	--	1	--	1	--	--	1	1	--	--	--	1	--	--	1	--	1	2	--	--	--	1	--	1	--	--
L	Teaching location	6	7	6	7	2	6	7	5	2	6	7	7	4	6	7	7	5	5	2	4	0	7	7	5	2	4
P	Location of software production	--	2	--	1	1	--	2	2	1	--	1	1	1	--	1	1	1	2	1	--	--	2	1	2	1	1
H	*Media Hardware Packages*	9	--	9	--	--	9	--	7	--	9	--	--	--	9	--	--	--	8	9	9	c	--	--	7	--	--

[a]D = Discussion, E = Examination, R = Review.

IV. GENERATING RESOURCE REQUIREMENTS FROM STUDENT FLOW

The final step in designing the instructional system is to simulate the flow of students through the example course and thereby determine the demand for essential resources.

With individual pacing of students, students will proceed through the course at a speed related solely to their learning ability and motivation. This is a matter of overall course strategy and has already led to certain key assumptions regarding the provision of resources. These assumptions have been quite general, but they now begin to become more specific.

Figure 2 shows a cumulative truncated normal distribution of student learning capability rates. The average is 1 and the standard deviation is .2. The slowest student will take 1.6 times as long to finish the course as the average student, and the fastest student .4 as long as the average. Other than having different learning rates, entering students are assumed to be homogeneous.

For simulation purposes, a capability figure is drawn from this distribution for each student as he enters the course, using a random number generator. Every time a student encounters a particular learning event, the time he takes to complete the event is equal to his capability figure multiplied by the average time for that event, as stipulated in the lesson analysis variable, x(1). For example, if student A has a .75 capability figure and he encounters an event for which $x(1) = 100$ minutes on the average, he would complete that event in 75 minutes. If his capability figure were 1.5, he would complete the event in 112.5 minutes.

There are three exceptions to this rule. All events that are of a fixed duration will obviously be completed by all students at the stated rate. For example, all students would take 15 minutes to view a 15-minute demonstration film, regardless of their learning ability. Also, no discussion between a student and an instructor can take place in less than 5 minutes, and such a constraint is imposed. Finally, an upper limit on the time slow students spend in evaluation events has been imposed and is equal to the mean time plus one standard deviation. This means that the slowest student will be allowed 20 percent more time than the average and no more.

With students moving through the course as individuals, the student entry rate can be flexible. Entries could be made randomly, or students could be entered in groups of uniform size at predetermined times. Entry intervals might be as short as one-half day, or as long as an entire course. The number of students per entry group

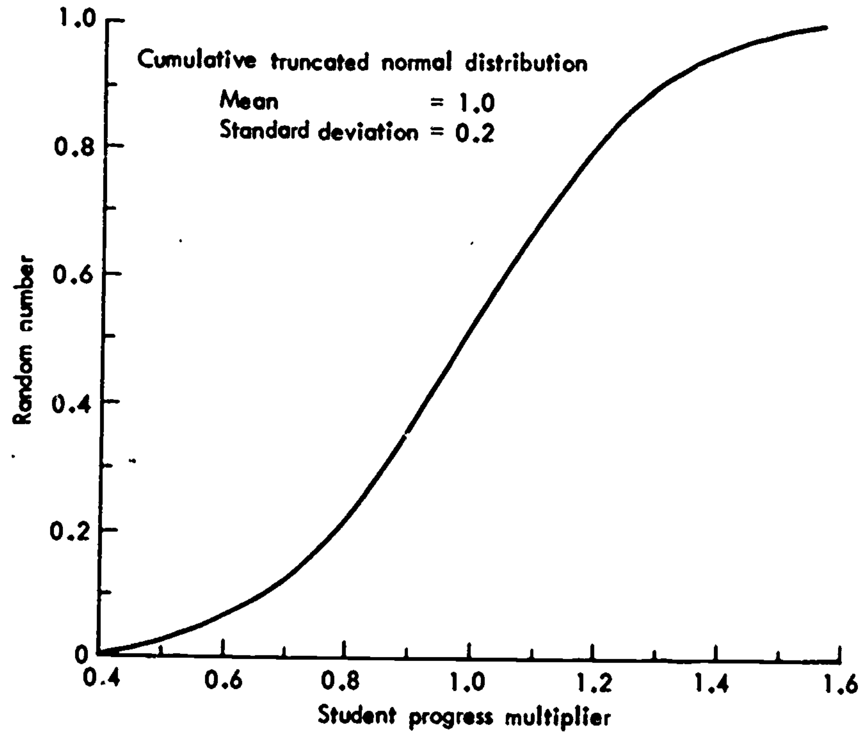

Fig. 2—Probability distribution for predicting rate of progress for each student

and the entry interval determine the average student load and the quantity of resources required to support the course.

Our hypothetical basic photography course lasts just under 2,900 minutes for the average student. Assuming a training day of 300 minutes (5 hours), 5 training days per week, weekends off, and 10 holidays per year, the average student will complete the course in approximately 14 calendar days or 2 weeks. The course runs continuously, and 2,600 students are graduated each year. That means that 100 students must graduate every 2 weeks. Given that the average course length is 2 weeks, the average student load would be 100 students in the course at any one time. Allowing 10 students to enter each training day—weekends and holidays excluded—results in a close approximation to these figures. Other possibilities would have been to enter 20 students every other training day or 40 students every fourth training day, and so on. Entry intervals shorter than 1 day were not considered.

In the course postulated, demands for media equipment, instructors, and software are determined by setting the requirements equal to the maximum number of students needing them at any one point in time. Given the assumptions about student flows, the maximums for different resources occur at different points in time. Calculating these maximums analytically is not feasible. Instead, estimates have been made using a relatively simple computer simulation model. A future computerized student flow model is described in Appendix C.

The model accepts specified numbers of students entering the course at prescribed time intervals, assigns a capability figure to each student, and simulates his progress through the course, event by event. The model does the necessary bookkeeping to keep track of where each student is in the course at all times. Because each event has associated with it a teaching location and an instructor or a communication medium and its software, keeping track of students by event makes it possible to produce a record of the number of students in each teaching location, and their use of instructors or media hardware and software. From this record, maximum, average, and frequency distributions of demand are calculated for each resource. In this example, we simulated a build-up period of 3,000 minutes, a little more than 1 course, and a steady-state operation of 9,000 additional minutes or approximately 3 "courses' worth" of steady-state operation.

The input to the model consists of the number of students entering at one time (10), the number of minutes between entries (300), the probability distribution of student capabilities, and the course description shown in the left half of Table 10. In the table, all events are arranged in order from first to last; the average times, x(1), are shown for each event, as are a teaching location code, L, a media hardware or instructor code, H, where appropriate, and a time constraint code, t. The time constraints were discussed earlier and are again explained in the footnote to the table.

Some of the results of the simulation are shown in the right-hand columns of Table 10. The first column shows the average number of students in each event throughout the 9,000 minutes of steady-state operation. The sum of these figures, 103.7, corresponds to our earlier estimate of an average student load of 100. The second column shows the largest number of students who appeared in each event simultaneously. Note that these range from a low of 3 to a high of 18. In order not to cause delays in student flow, resources sufficient to provide for the maximums must be made available. The final column shows the average time students actually spent in each event. The total time is less, by 2.5 percent, than the average time specified originally, due to the upper limit set on evaluation events.

Table 11 shows similar demand and usage figures for teaching locations, media hardware, and instructors. Notice, for example, that at least once during the course 59 instructors were required at the same time. Also, 55 students were using carrel units simultaneously. An obvious question is what fraction of the total time these maximums are actually required. Thus, the results of the simulation may not, ipso facto, define the resources it would be desirable to provide.

This is even more strongly suggested by the graphs in Figs 3 through 7. The data from which these graphs were produced are an output of the simulation model and are intended to suggest where constraints on the actual number of resources provided might be introduced in subsequent iterations of the system design process.

For example, the maximum number of students in tutoring rooms is 12 and the average is 4.6. However, the distribution labeled "percent of total time" shows that exactly 5 students were in tutoring rooms for 20 percent of the time, 4 for about 21 percent of the time, and 12 for only a small fraction of one percent of the total time. One might conclude from this chart that providing tutoring rooms sufficient to handle 7 or 8 students simultaneously would be more realistic than providing enough for 12. The "cumulative remainder" curve indicates that with 7 tutoring rooms, students would find them unavailable when needed no more than 7.5 percent

Table 10

INPUTS AND OUTPUTS OF STUDENT FLOW MODEL

Inputs							Outputs		
Sequence Number	Lesson	Event	Time in Minutes x(1)	Teaching Location L	Media Hardware H	Time Constraint t[a]	Average No. of Students	Maximum No. of Students	Average Minutes per Student
1	1	1	35	5	7	--	1.3	11	34.7
2	1	2	120	5	8	--	4.4	11	120.2
3	1	3	120	5	3	2	4.4	11	119.3
4	1	4	75	5	8	--	2.7	10	73.2
5	1	5	35	6	9	1	1.3	7	34.3
6	1	6	20	7	--	3	.7	5	19.3
7	2	1	30	5	8	--	1.1	6	29.4
8	2	2	120	5	8	--	4.4	10	117.7
9	2	3	30	5	6	2	1.1	5	30.0
10	2	4	150	2	9	--	5.[illegible]	11	147.4
11	2	5	18	6	9	1	.6	5	17.6
12	2	6	12	7	--	3	.4	5	11.4
13	2	7	15	2	--	3	.5	5	14.2
14	3	1	35	5	--	--	1.3	6	34.5
15	3	2	60	5	--	--	2.2	7	59.2
16	3	3	30	5	--	--	1.1	5	29.4
17	3	4	30	5	--	--	1.1	5	29.9
18	3	5	60	5	7	--	2.2	8	59.2
19	3	6	60	5	-	--	2.2	9	59.1
20	3	7	120	2	9	--	4.4	10	118.3
21	3	8	45	5	--	--	1.6	8	44.4
22	3	9	340	2	9	--	12.4	18	320.0
23	3	10	32	6	9	1	1.2	5	31.4
24	3	11	23	7	--	3	.8	4	22.1
25	3	12	6	5	7	3	.2	3	5.4
26	3	13	36	2	--	3	1.3	5	34.9
27	4	1	15	5	8	--	.5	4	14.5
28	4	2	30	0	9	--	1.1	5	29.2
29	4	3	30	5	6	2	1.1	5	29.9
30	4	4	15	5	--	--	.5	4	14.4
31	4	5	60	4	9	--	2.2	6	59.1
32	4	6	60	4	9	--	2.2	6	59.1
33	4	7	10	6	9	1	.4	5	9.5
34	4	8	3	7	--	3	.1	3	2.4
35	4	9	2	7	--	3	.1	3	1.5
36	4	10	12	4	--	3	.4	5	11.3
37	5	1	90	5	--	--	3.3	9	89.0
38	5	2	30	5	--	2	1.1	6	29.8
39	5	3	30	5	--	--	1.1	6	29.4
40	5	4	30	2	9	2	1.1	6	29.9
41	5	5	30	0	9	--	1.1	5	29.2
42	5	6	60	0	9	--	2.2	7	59.2
43	5	7	180	2	9	--	6.6	13	175.2
44	5	8	15	6	9	1	.5	5	14.6
45	5	9	11	7	--	3	.4	5	10.3
46	5	10	4	7	--	3	.1	3	3.5
47	6	1	27	5	--	--	1.0	5	26.6
48	6	2	25	5	8	--	.9	5	24.5
49	6	3	49	2	9	--	1.8	7	48.5
50	6	4	12	4	9	--	.4	4	11.5
51	6	5	7	0	9	--	.2	3	6.5
52	7	1	169	7	--	3	6.1	13	164.3
53	7	2	18	7	--	3	.6	5	17.2
54	7	3	15	5	7	3	.5	5	14.3
55	7	4	128	2	--	3	4.6	12	124.9
56	7	5	30	4	--	3	1.1	5	29.[illegible]
			2854				103.7		2784.8

[a] $t = 1$, discussion must be ≥ 5 minutes; $t = 2$, fixed duration must be $x(1)$; $t = 3$ evaluation must be $\leq (x(1) + 10)$.

Table 11

ESTIMATED REQUIREMENTS FOR TEACHING LOCATION CAPACITY AND MEDIA HARDWARE/INSTRUCTORS FROM STUDENT FLOW SIMULATION MODEL

Teaching Locations and Media Hardware or Instructor	Number of Students			Average Minutes per Transaction
	Current[a]	Average[b]	Maximum	
Teaching Locations				
L Description				
0 Tutoring rooms	9	4.6	12	31.0
2 Outdoors but close	39	38.2	52	113.8
4 Small laboratory	5	6.3	14	34.1
5 Carrel units	32	41.3	55	46.6
6 Discussion rooms	4	4.0	12	21.4
7 Paper-and-pencil testing area	11	9.4	20	28.1
	100	103.8		
Media Hardware/Instructors				
H Description				
0 Texts: conventional or programmed	34	33.7	46	36.5
3 Sound-motion film viewers	4	4.4	11	119.3
6 Silent-motion film viewers	1	2.2	8	30.0
7 Sound-slide set projectors	1	4.2	19	28.5
8 Class V teaching machines	13	14.1	28	63.3
9 Instructors	47	45.2	59	67.5
	100	103.8		

[a]Number of students at exactly 12,000 course minutes.

[b]Averages calculated after a 3,000-minute course build-up period.

of the time; whether or not this would be acceptable is at this point a matter of judgment.

Figures 8 through 12 present similar demand information for media hardware and for instructors. In Fig. 12 we see that at least 29 instructors are always being used, and at most 55 are required. Further, 58 percent of the time, between 44 and 50 instructors are required. Instructors seem to be used more efficiently than tutoring rooms.

From the limited example above, one might conclude that a reduction in tutoring rooms would have a less serious impact on student flow than would a reduction in the number of instructors. This is probably true, but the results can only be determined by introducing such a constraint and rerunning the simulation model. There are interactions, the results of which are difficult to predict. If students are forced to wait at one point in the course they may, by bunching up, arrive at other points in larger groups and require more of another kind of resource than they would if they were allowed to flow smoothly. A reduction in the quantity of one resource may well cause an increase in the requirement for one or more others. The simulation model provides the ability to test the implications of such changes.

The requirement for software is also obtained from the simulation results. The nature of the software is implied by the presentation method, M(1), for each event. As has already been seen, the maximum number of students participating in each event simultaneously is shown in Table 10. When media software is needed, a

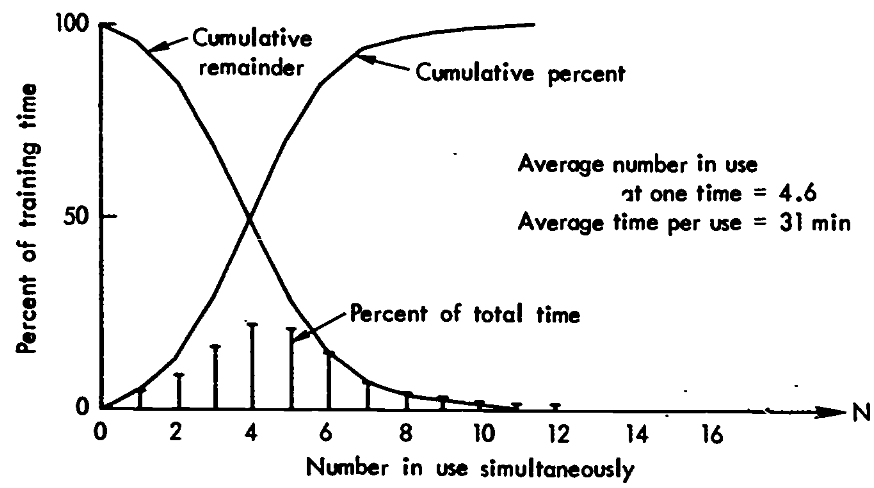

Fig. 3—Utilization of 12 tutoring rooms

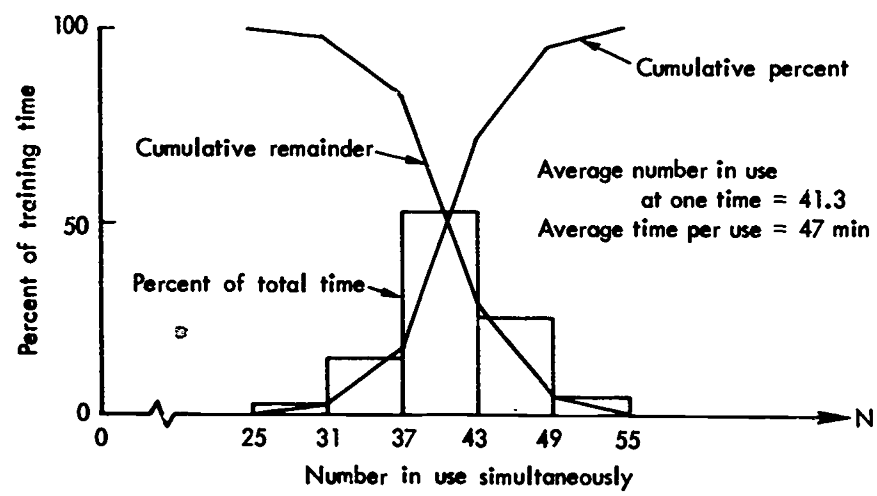

Fig. 4—Utilization of 55 carrel units

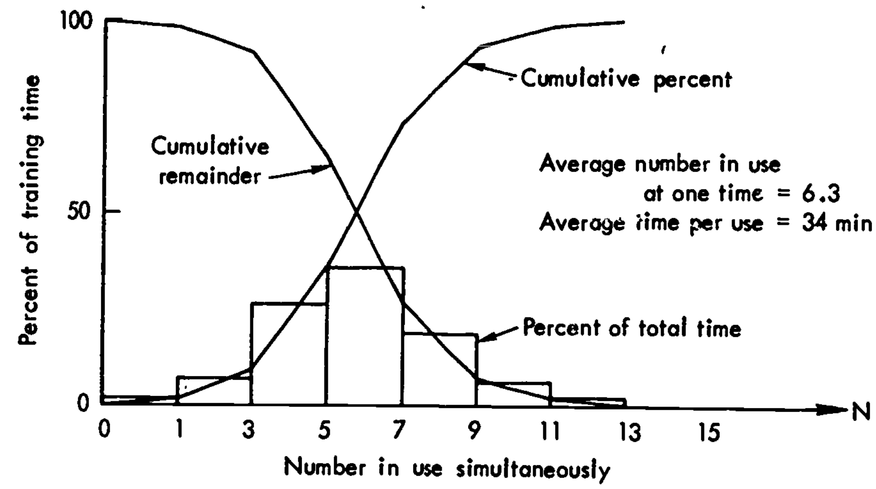

Fig. 5—Utilization of 14 darkrooms

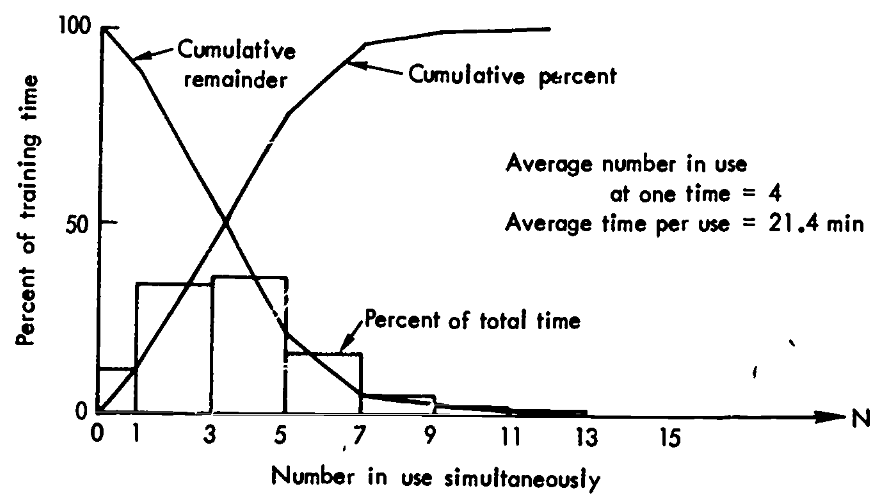

Fig. 6—Utilization of 12 discussion rooms

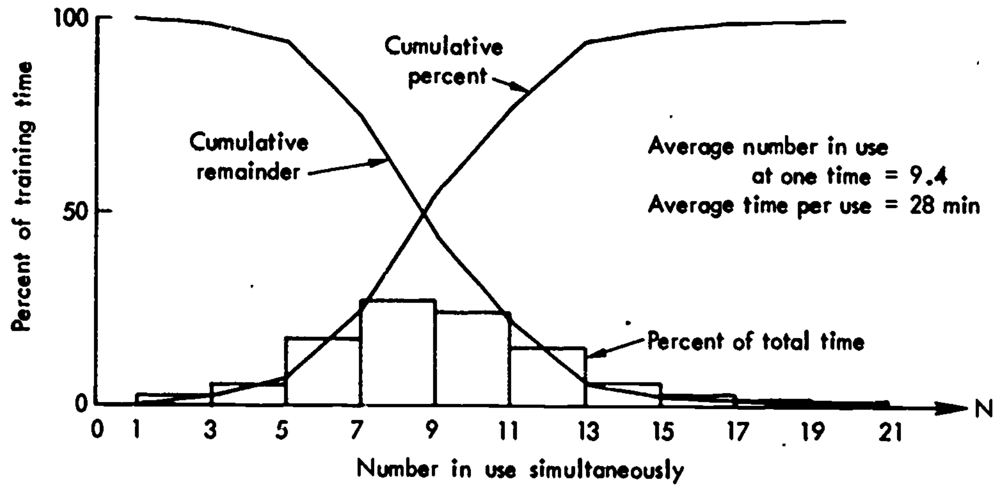

Fig. 7—Utilization of 20 paper-and-pencil testing facilities

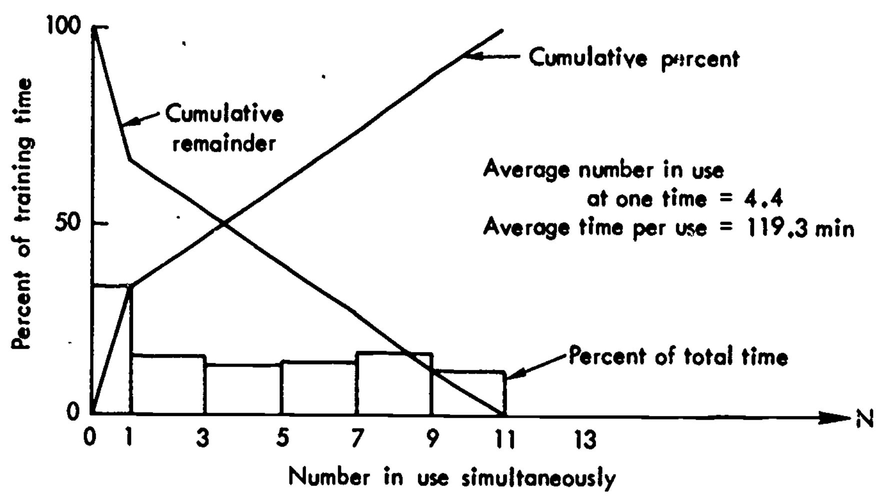

Fig. 8—Utilization of 11 sound-motion film viewers

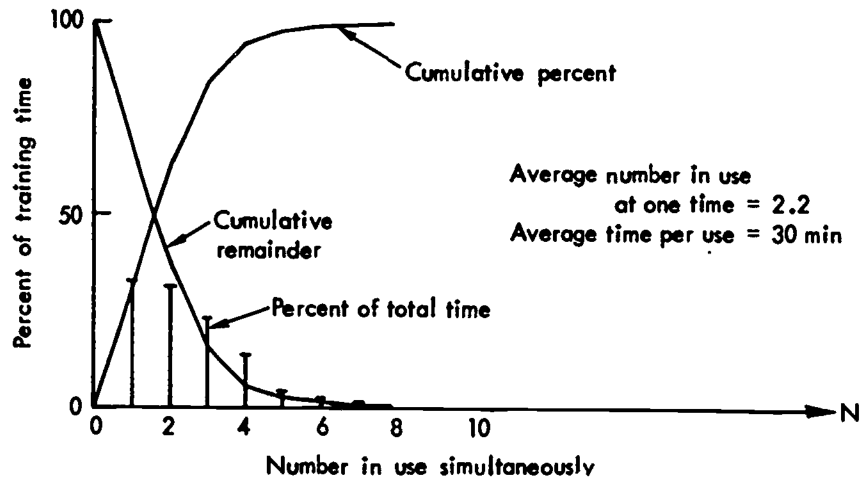

Fig. 9—Utilization of 8 silent-motion film viewers

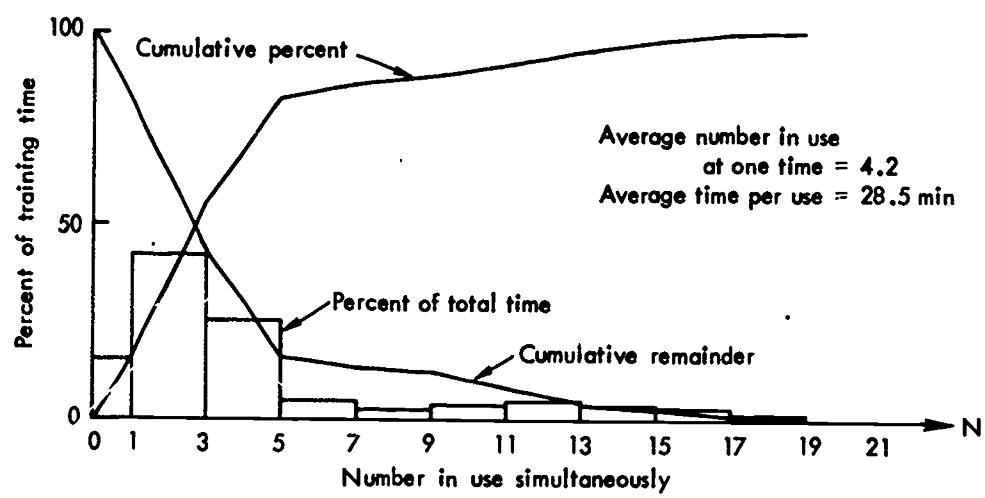

Fig. 10—Utilization of 19 sound-slide set projectors

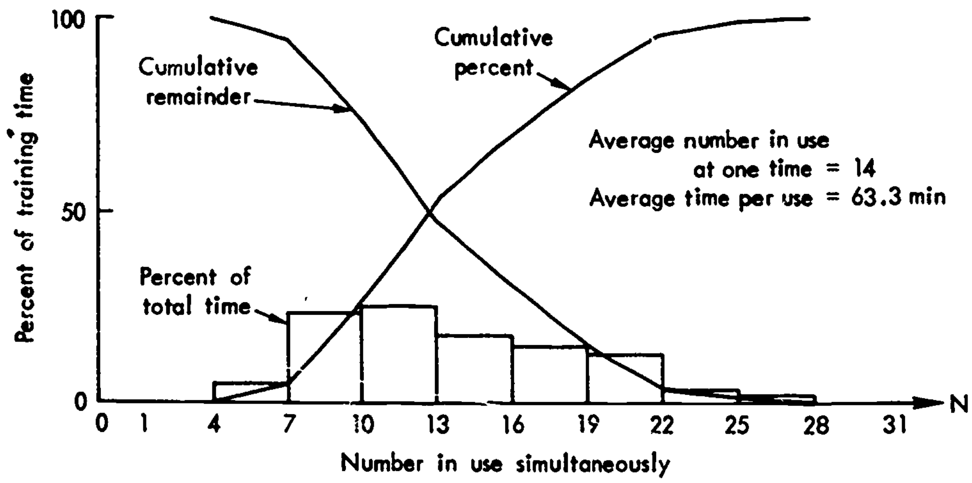

Fig. 11—Utilization of 28 class V teaching machines

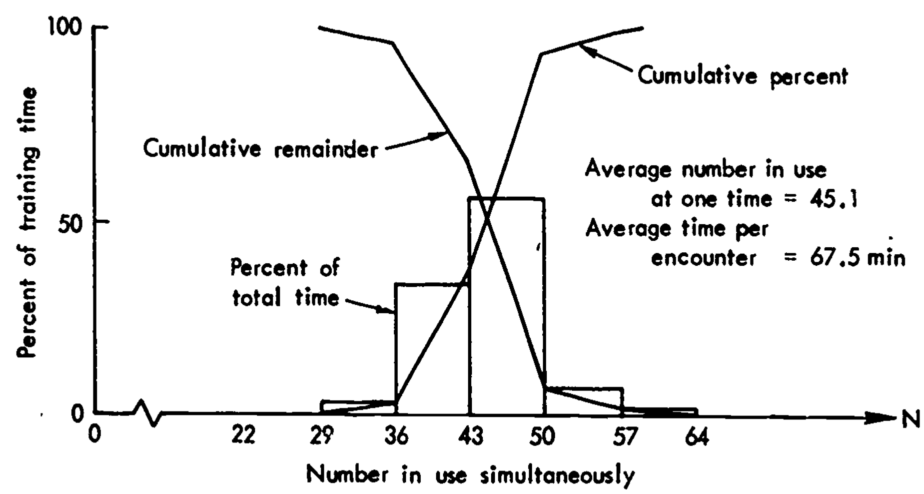

Fig. 12—Utilization of 59 instructors

separate copy must be available for each student. Combining this information with that of Tables 6 and 8 leads to the summary of software requirements shown in Table 12.

Notice that—unlike the media hardware, instructors, and teaching locations—software is associated with separate learning events, and the number of minutes of software required to be produced is obtained from the curriculum analysis variable x(16) rather than x(1). Variable x(16) is running time only, stripped of all time spent during conventional instruction in discussion or other interaction among students and among students and instructors. Discussion of the instructional content is separately scheduled, as described above under "Planning Discussion Time."

Requirements for texts and guides are included as items of software but with a maximum equal to the total number of students and instructors, as shown in the note to Table 12. The times as indicated do give insight into the subjects to be covered and the number of pages of material to be prepared. These figures will be used to estimate the cost of producing these items.

Table 12

SOFTWARE REQUIREMENTS

Item	Lesson, Event	x(16)	Maximum Copies
Sound-motion film, M(1) = 1	1,3	90	11
Silent-motion film, M(1) = 2	2,3	30	5
	4,3	25	5
Sound-slide set, M(1) = 4	1,1	25	11
	3,5	50	8
	3,12	6	3
	7,3	15	5
Class V teaching machine script, M(1) = 5	1,2	60	11
	1,4	50	10
	2,1	20	6
	2,2	100	10
	4,1	15	4
	6,2	25	5
Programmed text, M(1) = 6	3,1	30	(a)
	3,2	50	(a)
	3,3	25	(a)
	3,6	50	(a)
	3,8	35	(a)
	4,4	15	(a)
	5,1	75	(a)
	5,3	30	(a)
	6,1	27	(a)
Written questions for evaluation, M(1) = 7	1,6	20	(a)
	2,6	12	(a)
	3,11	23	(a)
	4,8	3	(a)
	4,9	2	(a)
	5,9	11	(a)
	5,10	4	(a)
	7,1	169	(a)
	7,2	18	(a)
Conventional text, M(1) = 8	3,4	25	(a)
	5,2	20	(a)
Instructor's lesson guide, M(8) = 1	2,4	10	(a)
	3,7	30	(a)
	6,3	49	(a)
Instructor's evaluation guide, M(8) = 3	2,7	15	(a)
	3,13	36	(a)
	4,10	12	(a)
	7,4	128	(a)
	7,5	30	(a)

[a]Every student has his own conventional text, programmed text, and workbook. Every instructor has his own conventional text, programmed text, workbook, lesson guide, and evaluation guide.

V. ESTIMATING THE COST OF THE INSTRUCTIONAL SYSTEM

METHODOLOGY

We knew of no complete set of methods for estimating the costs of the example course. The bits and pieces of methodology that are available have been used here. Much new methodological development has also been required. The resulting cost analysis, which we carried out by hand, forms a basis for future development of a computer-based cost estimating model.

Initial investment costs and annual operating costs were computed separately to make it easier to observe the impact of time on total cost. Investment and operating cost were each broken down into resource and/or functional categories to emphasize the requirements for special kinds of resources and to help relate the demand for these resources to the characteristics of the course and the instruction.

Eventually it will be possible to distinguish not only between investment and operating cost but between fixed costs and those that vary with student load. The *fixed* component is unaffected (within limits) by the number of students taking the course. The size of the *variable* component is directly related to the number of students taking one course. Some effort has been made to prepare for this, particularly in the personnel area. However, to save on the number of calculations required, this distinction has not been carried beyond that point. Making the distinction involves no conceptual problems and could have been done at the expense of additional time and effort. Its main value would be to allow a more accurate estimate of the marginal cost per student.

The costs estimated are those that would be incurred if this course were introduced at an existing Air Force Technical Training Center. They are based on the assumption that nothing has been inherited or obtained free of charge. All required facilities, equipment, software, stocks and supplies, and even the initial training costs of the permanent party military personnel, have been included in the investment or start-up costs. To the extent that many of these assets would already have been obtained, in the real world, the investment costs would be reduced. In this example, however, all costs are incremental costs.

The annual operating costs include all recurring expenses, such as maintenance and replacement of facilities, software and equipment, pay of personnel, replacement training of personnel, consumption of stocks and supplies, and so on.

The costs are incurred at several organizational levels. To relate some of them to a single course requires allocation decisions. For example, the general organizational structure posited for this example consists of a school, several departments within the school, and several branches within each department. Courses are apportioned among the branches. Costs resulting from the introduction of a new course may be incurred at each of these levels. Administrative cost is a case in point. It has been prorated to the example course in proportion to the relative annual student-weeks of training produced at each organizational level and in the course itself.

Four different categories of cost are indirectly generated by the course—instruction, support of instruction, administration of instruction, and indirect. They are most easily thought of in terms of personnel, the jobs they perform, and the costs they incur while performing these jobs. The cost of instruction includes the immediate supervision of the instruction. Costs for immediate support of instruction include such items as curriculum maintenance and maintenance of media hardware and training aids. Administration includes the costs of receiving, processing, and discharging students; top-level supervision; and general management. Indirect cost includes housing, feeding, and generally supporting the people and activities mentioned above. These indirect costs are usually referred to as base operating support costs. To the extent that they are increased by adding the example course, the increase is included in the total. Thus, the cost estimates presented here are comprehensive in the sense that they include *all* of the costs that would be incurred by adding the course.

One or more cost-estimating relationships will be required for each category of cost estimated. In some cases these may be simple per-man factors; others, such as those used to estimate facilities cost, may be relatively complex models in their own right.

Any cost-estimating relationship, whether simple or complex, consists of two parts: the structural form that includes the required variables and equation parameters, and the values to be assigned to the parameters. In this exercise, most of the emphasis has been on specifying the structure, and not on obtaining precise estimates of the parameter values. In all cases, however, the values used are believed to be representative.

The ultimate goal of this and subsequent exercises is to prepare a computer-based cost-estimating model. For this reason, the methods employed here have, in all cases, been documented in Appendix B in more depth than would normally be the case.

RESULTS OF COST ANALYSIS

A summary of the costs required to install and operate the example course is shown in Table 13. These are, of course, estimates, subject to error. Research that would make them more precise has yet to be done. However, considerable effort has gone into making them comprehensive. While the absolute values may well be in error, it is believed that the distribution of cost among categories and the relative magnitudes of the individual estimates is reasonable, given the assumptions. It should be remembered that this is a maximum-cost estimate. Most of the investment cost shown goes for facilities that would normally be available at an existing school.

Table 13

ESTIMATED COST FOR VARIABLY AND INDIVIDUALLY PACED COURSE IN BASIC PHOTOGRAPHY-- 2600 GRADUATES PER YEAR

(Costs in thousands of dollars)

Item	Initial Investment	Annual Operating
Base facilities	1491	90
Furnishings and equipment	671	67
Media hardware	14	3
Media software	201	75
Training aids	13	3
Stocks and supplies	14	62
Personnel training	395	79
Pay and allowances	---	1307
Personnel travel	---	130
Utilities	---	15
Total	2799	1831

An investment of approximately \$2.8 million would be required, of which \$1.5 million is for construction of facilities and \$0.7 million for furnishings. Investment in media hardware, software, and related special furnishings adds up to approximately \$230,000, of which over \$200,000 is for the initial investment in media software. Even with the heavy emphasis on the use of communication media, the proportion of total investment traceable to that source is relatively low.

Operating cost for one year amounts to approximately \$1.8 million, of which the largest single part, pay of personnel, is \$1.3 million. This partly reflects the use of instructors in a tutorial mode, to carry out the assumption that each student must proceed as an individual and must never have to wait for resources. This suggests that considerable savings in this area might accrue if even greater use were made of media.

The operating costs immediately traceable to the use of media amount to approximately \$78,000. The largest share is for revision and replacement of films, texts, and workbooks. As with the investment, communication media account for a relatively small portion of the total annual operating cost. Unlike investment costs, operating costs are not reducible by inheriting free goods.

VI. CONCLUSIONS

RESULTS TO DATE

This exercise has made contributions in two major areas. The most obvious contributions have to do with the specific example used to illustrate the design process. Individual variable pacing results in more efficient use of student time and presumably produces an output of higher quality overall. This is suggested by the fact that each student in the innovative course would spend over half of his time in face-to-face tutorial sessions.

Under conventional methods, the course length for all students is established by the length of time it takes the slower students to master the subject material. In the example case, this would mean that the average course length would be more like 3 weeks than 2, and that for the same graduate output, the average student load would be 150 instead of 100. Many of the costs would go up proportionally. This would certainly be true of those associated with student housing and temporary duty travel. At the same time, all but the slowest students would be wasting a significant portion of their time—as much as two-thirds for the brightest ones.

Even though communication media were employed extensively in the example course, their costs account for a relatively small fraction of the total cost: 8 percent of the investment cost and 4 percent of the operating cost. At the same time, personnel other than students account for approximately 50 percent of the investment cost and almost 70 percent of the operating cost. This seems to argue, on economic grounds alone, for more extensive substitution of communication media for instructors in the teaching process.

The instructional program resulting from the application of a highly individualized teaching method to the course in basic photography has been shown to have a cost similar (though higher) than photography courses taught in ways more representative of current Air Force practice. More importantly, the rates of utilization of instructional resources (shown in detail by the outputs of the student flow model) and the distribution of costs among elements of the instructional program indicate that relatively minor changes could effect appreciable savings without impairing the individualized nature of the instruction. In particular, a slight relaxation of the design criteria to permit some queuing and a greater use of media for classroom instruction and demonstrations would reduce the facilities and equipment required, on the one hand, and the number of instructors needed, on the other. The effects of such changes could be explored in a few days, using the MODIA tools already developed.

The same tools would permit rapid examination of other variations that might be of interest. Among these are:

- Variations in student entry intervals and entry rates
- Variations in the distribution of student learning rates
- Variations in the sequencing of course content
- Different ground rules for examinations, reviews, and discussions
- Application of the individualized method to a different course

The exercise has implications broader than the specific example, however. Perhaps of primary importance to the design team is the confidence that has been engendered in the feasibility of developing systematic approaches of general applicability to the design of instruction. Although there are several areas in which further basic analysis is needed (discussed below), the team found that at almost every point it was possible to resolve issues by applying simple logic and rules of thumb. In addition, despite the developmental nature of most of the effort that went into working out the example, the total time required was on the order of six weeks. A few days at most would suffice to explore the effects, that can be treated within the methodology developed so far, of changes in design criteria or teaching strategy.

A second significant result is that going about the design of programs of instruction in a systematic way does, indeed, encourage the examination of alternative approaches to instruction. The provision of details on resource utilization rates and student flow, *which can be traced directly to decisions regarding design criteria and teaching method,* encourages the designer to reexamine these prior decisions with an eye to improving the efficiency of the program of instruction.

As we worked through the design process, we discovered a number of areas in which further research seems promising. For example, it became clear that additional decisions were needed to handle the scheduling of discussion sessions, the sequencing of reviews that concerned several major types of instruction, and the order of presentation of items on examinations. And during the construction of the student flow model, it became evident that a completely generalized model would not only treat problems of grouping students and the provision of special instruction (such as remedial or advanced) to subsets of the student population, but would also consider the sharing of resources among several concurrent courses.

And finally, as we worked through the design process, we also gained important insights into the workings of an instructional program that might not otherwise have occurred to us. For example, it became evident that the needs of students in highly individualized courses such as this one would most conveniently be met by designing facilities, materials, and equipment for use in small units and that some degree of portability was highly desirable. In addition, because the cost of successive use of recorded materials is low, in a course such as this one with high student loads and individual use of instructional resources, instruction presented by recorded media is an inexpensive alternative to the face-to-face tutorial.

WHAT REMAINS TO BE DONE

The process of synthesis of a program of instruction can be much more general and automatic than we have made it to date. We have already discussed the need for and possible payoffs to a generalized model of student flow. An approach to the development of such a model is described in Appendix C. In a similar vein, the cost analysis part of the design process can be completely computerized, as has been done in other areas.[13] This will permit rapid estimation of the cost impacts of the wide range of program designs that can be generated.

A questionnaire for the analysis of local resources and other relevant matters should be developed, along the lines of the curriculum analysis questionnaire. This is a straightforward task that would probably take only a few months for design and checkout.

Two areas of research are much less clear-cut than the foregoing, however. One is the procedure for deciding on the specific configuration of media systems and personnel on the basis of stated instructional strategy, existing resources, and design criteria. At this point we are not certain that we can automate all or even a large part of this process—or that it would be desirable to do so. Fundamental research will be needed to resolve this question.

The other difficult area is the question of the role that the user should play in the design process. You will recall that we decided it was best to involve the user as much as possible, relieving him only of those chores that require little judgment and can be handled in a routine fashion. We do not know, however, how deeply we can involve him without overwhelming him with detail; nor do we know whether the design tools can be made to communicate with him effectively enough to elicit his wishes and stimulate his imagination. It is still possible, at this point, that only minimal involvement of the user can be expected. This issue can be resolved only by field trial.

Full development promises to be a long-term effort, but, as has been indicated here, many important benefits will be derived along the way. A major conclusion, therefore, is that the methodological research already under way should be continued. New examples should be chosen, new strategies should be examined. As this is done, the required tools will evolve, and, more importantly, the continuing benefits to educational system planning will be great and worth the cost of the research.

[13] W. [illegible], *The Pilot Training Study: Personnel Flow and the PILOT Model*, The Rand Corporation, RM-6080-PR, December 1969; M. L. Rapp, et al., *Project R-3, San Jose, Calif.: An Evaluation of Results and Development of a Cost Model*, The Rand Corporation, R-672-SJS, March 1971.

Appendix A

MASTER CODE LIST

CURRICULUM ANALYSIS

x(1) Learning event time in minutes
x(2) Housekeeping time in minutes
x(3) Interrelated concepts or skills?
- 1 Yes
- 0 No

x(4) Special instructional events
- 1 For students who lack prerequisites
- 2 Skipped by students who have already shown mastery of the subject matter
- 3 Skipped by students not bright enough to grasp subject matter in allotted time
- 4 Could be skipped by extremely bright students
- 5 Provided as enrichment for students with time left after finishing assigned work
- 6 Remedial instruction for students found to have difficulty mastering assigned subject matter

x(5) Learning event categories

Type I Instruction

- 1 No special equipment or facilities required for presentation
- 2 Special equipment or facilities required for presentation

Type II Instruction

Performance of:

- 3 Team skills
- 4 Individual skills

Pure demonstration of:

- 5 Team skills
- 6 Individual skills

Follow-me demonstration of:

- 7 Individual skills.

Type III Instruction

Performance of:

8 Team skills
9 Individual skills

Pure demonstration of:

10 Team skills
11 Individual skills

Follow-me demonstration of:

12 Individual skills

D Discussion of media presentation
R Planned reviews
E Formal evaluation

x(6) Is minimum rate of performance an objective?
1 Yes
0 No
x(7) What is the team size?
x(8) Additional support personnel required (give number):
Instructor level
Student assistant level
x(9) Is instructor required for knowledge of correct responses?
1 Yes
0 No
x(10) Level of supervision required for safety
0 Not necessary
1 Instructor
2 Instructor aide
3 Student monitor
x(10a) Number of students per supervisor
x(11) Special area required to produce presentation
0 None
1 A distant location
2 Outside but near school
3 Large laboratory, shop, etc.
4 Small laboratory
x(12) Are selected responses satisfactory for evaluation?
1 Yes
0 No
x(13) Is special equipment required to present?
1 Yes
0 No
x(14) Source of special equipment
3 Borrowed
4 Purchased
5 Already on hand
x(15) Number of viewers who can see one face-to-face presentation
x(16) Time in minutes of one presentation or demonstration or presentation of problems and directions
x(17) Is special material required for performance?
1 Yes
0 No
x(18) Is the learning event regularly scheduled?
1 Yes
0 No

x(19) Is the subject matter to be formally evaluated?
- 1 Yes
- 0 No

x(20) Number of months between revisions of curriculum content

x(21) Appropriate media class
- 0 None appropriate
- 1 Audio-motion-visual
- 2 Audio-still-visual
- 3 Audio-semimotion
- 4 Motion-visual
- 5 Still-visual
- 6 Semimotion
- 7 Audio
- 8 Print

BASIC INSTRUCTIONAL STRATEGY

S Strategy number as output by DISTAF program (R-1019-PR)

6 Presenter
- 1 Instructor
- 2 Any appropriate communication medium
- 3 Student leader
- 4 Adaptive program
- 5 Fixed-duration program
- 7 Response-paced program

7 Integrated stimuli included in presentation?
- 1 Yes
- 0 No

8 Recording of student responses
- 1 Permanent recording
- 0 None

9 Constructed responses required?
- 1 Yes
- 0 No

10 Machine scoring of selected responses?
- 1 Yes
- 0 No

14 Pacer
- 1 Student leader
- 2 Individual student
- 3 Instructor
- 4 Response-paced program

29 Is knowledge of correct response provided to student?
- 1 Yes
- 0 No

MEDIA SYSTEM CHARACTERISTICS

M(1) Presentation medium
- 0 Instructor
- 1 Sound film (motion)
- 2 Silent film (motion)
- 3 Silent filmstrip (still)
- 4 Slide set (sound)
- 5 Class V teaching machine
- 6 Programmed text
- 7 Written questions for examination
- 8 Conventional text or workbook

M(2) Pacer of presentation
- 1 Students' correct responses
- 2 Students' judgment (with maximum time limit for examinations)
- 3 Instructor
- 4 Fixed-duration presentation

M(3) Requirement for internal random access (study)
- -- Not applicable when presenter is an instructor or for formal examinations
- 0 No
- 1 Yes

M(4) Pacing control device
- -- Not applicable when instructor is pacer, or student controls pacing, or for fixed-duration presentation
- 1 Response selection device for response pacing of projections, viewers, etc.
- 2 Response selection component, e.g., with class V teaching machine
- 3 Control that will provide: stop-start, freeze frame, fast forward, fast rewind, etc., for use with projectors and viewers when student is allowed to study
- 4 Simple on-off switch for use when control is left to individual student but no internal random access is provided

M(5) Source of immediate knowledge of results
- -- Not applicable for pure demonstrations or examinations
- 1 Reaction of machine when response-paced
- 2 Medium provides examples of correct responses
- 3 Instructor's evaluation

M(6) Permanent recording method
- -- Not applicable for pure demonstrations
- 0 None, as specified by strategy (8)
- 2 Instructor's notes and/or student product
- 3 In text or workbook--standard form for formal examinations
- 4 Record kept by response choice
- 5 Paper-and-pencil mark-sense system

M(7) Portable media hardware required
- -- Not applicable if medium is text or workbook or if presenter is instructor or for paper-and-pencil examinations
- 0 No
- 1 Yes

M(8) Instructor provided with guide
- -- Not applicable when presenter is a medium
- 0 None at all
- 1 Lesson
- 2 Programmed
- 3 Examination

M(9) Method of machine scoring
- 0 None
- 1 Mark-sense
- 2 Counter for correct responses on response device
- 3 Card reader and tabulator

ACTIVITY LOCATIONS

L Instruction or evaluation
- 0 Classroom

2 Outdoors, but close to school
4 Small laboratory
5 Carrel area
6 Discussion room--office
7 Paper-and-pencil testing area

P Production
0 None
1 Print shop or reproduction center
2 Small studio or workroom
3 On location--nearby
4 On location--distant
5 Elaborate, large studio

HARDWARE AND/OR INSTRUCTOR

H Media hardware
1 Portable Super 8 sound-motion film viewer with response-pacing control by an interlocked response selection device
2 Portable Super 8 sound-motion film viewer with: stop-start, freeze frame, fast rewind, and fast forward controls
3 Portable Super 8 sound-motion film viewer with on-off control only
5 Portable Super 8 silent-motion film viewer with: stop-start, freeze frame, fast rewind, and fast forward controls
6 Portable Super 8 silent-motion film viewer with on-off control only
7 Portable Super 8 sound-slide-set projector and audio cassette system
8 Portable class V teaching machine with response selection component
9 Instructor

Appendix B

DETAILS OF COST ANALYSIS

The complete chart of accounts or set of cost elements is shown as Table 14. Media hardware and software costs, which are of primary interest in this example, are shown in considerable detail. The detail shown in the chart of accounts could be condensed, for some purposes. Here it is intended both as a display device and as a checklist of items to be considered in deriving a cost estimate.

PERSONNEL REQUIREMENTS

The details of the process by which these estimates were made will now be described. We begin by deriving requirements for personnel. Personnel are always a potentially scarce resource, particularly if personnel possessing special skills are required. They are also prime generators of other resource requirements: housing, pay and allowances, services, etc. It is, therefore, common practice to estimate personnel requirements first, and this practice has been followed here.

The personnel estimating method used is essentially that used by Allison to analyze manpower requirements and cost for alternative methods of training aircraft pneudraulic repairmen. The distribution of personnel by grade and the 1970 pay and allowance factors presented in that study have been used here without alteration (Tables 15 and 24). The only major difference was in estimating the requirement for instructors. Allison's model assumes conventional classroom instruction and makes estimates accordingly. In our example, with variable individual pacing, the requirement for instructors has been taken directly from the student flow simulation model output, as described in Sec. IV. In fact, the simulation model has provided most of the basic inputs to the specification of requirements for facilities, equipment, and software.

Table 14

ESTIMATED COSTS FOR VARIABLY AND INDIVIDUALLY PACED COURSE IN BASIC PHOTOGRAPHY
2600 GRADUATES PER YEAR

(Average course length two weeks)

INITIAL INVESTMENT

Base Facilities		
Tutoring rooms	$ 30,000	
Discussion rooms	30,000	
General office space	110,000	
Paper-and-pencil testing area	8,800	
Carrel and media storage area	23,280	
Darkrooms	10,500	
Training aids and media mtc. shop	8,000	
Personnel family housing	990,000	
Student housing-dormitories	281,250	
Total base facilities		$1,491,830
Portable Media Hardware		
Sound-motion film viewers	$ 3,850	
Silent-motion film viewers	1,200	
Sound-slide set projectors	2,850	
Class V teaching machines	5,600	
Total media hardware		$ 13,500
Media Software		
Sound-motion films	$ 94,410	
Silent-motion films	44,395	
Sound-slide sets	10,720	
Teaching machine programs	16,275	
Texts and workbooks	32,684	
Lesson and evaluation guides	2,765	
Total media software		$ 201,247
Training Aids		
Cameras and accessories	$ 10,000	
Darkroom equipment	2,800	
Total training aids		$ 12,800
Other Furnishings and Equipment		
Tutoring room furniture	$ 4,200	
Discussion room furniture	4,200	
Paper-and-pencil test area furn.	2,700	
Carrel area furniture	7,075	
Base support furniture and equip.	652,000	
Total other furn. and equip.		$ 670,175
Initial Stocks and Supplies		
Darkroom supplies and film	$ 4,333	
Training aids mtc. materials	106	
Media hardware mtc. materials and eq.	1,170	
Facilities mtc. materials	2,500	
General office supplies	617	
Personnel supplies	5,433	
Total stocks and supplies		$ 14,159
Personnel Training		
Administration personnel	$ 20,000	
Instructors and supervisors	280,000	
Direct support personnel	10,000	
Ind. base admin. and support pers.	85,000	
Total personnel training		$ 395,000
GRAND TOTAL		$2,798,711

ANNUAL OPERATING COST

Base Facilities		
Maintenance materials	$ 15,000	
Replacement	74,591	
Total base facilities		$ 89,591
Media Hardware Replacement		
Sound-motion film viewers	$ 185	
Silent-motion film viewers	159	
Sound-slide set projectors	398	
Class V teaching machines	1,065	
Total replacement		$ 1,807
Media Software Rev. and Repl.		
Sound-motion films	$ 22,734	
Silent-motion films	11,688	
Sound-slide sets	8,135	
Teaching machine programs	4,923	
Texts and workbooks	26,468	
Lesson and evaluation guides	554	
Total rev. and repl.		$ 74,502
Training Aids Mtc. and Repl.		
Cameras and accessories	$ 2,500	
Darkroom equipment	420	
Total mtc. and repl.		$ 2,920
Furnishings and Equipment Repl.		
Tutoring room furniture	$ 420	
Discussion room furniture	420	
Paper-and-pencil test area furn.	270	
Carrel area furniture	708	
Base support furn. and equip.	65,200	
Total replacement		$ 67,018
Supplies Consumption		
Darkroom and film	$ 26,000	
Media hardware mtc. materials	1,219	
Office supplies	3,700	
Personnel supplies	32,600	
Total supplies		$ 63,519
Personnel Training		
Administration personnel	$ 4,000	
Instructors and supervisors	56,000	
Direct support personnel	2,000	
Ind. base admin. and spt. pers.	17,250	
Total training		$ 79,250
Pay and Allowances		
Permanent party	$1,032,464	
Students	274,400	
Total pay and allowances		$1,306,864
Personnel Travel		$ 128,928
Utilities		$ 15,375
GRAND TOTAL		$1,827,774

Table 15

INPUT VALUES FOR CALCULATING MANPOWER REQUIREMENTS

Symbol	Variable	Value
d(5/11)	Average annual student load	100*
e(2)	Number of entry groups per month	20*
k(4)	Number of shifts	1*
k(23)	Available working hours per instructor per month	140
e(21)	Annual student weeks of training in course	5,000*
k(46)	Annual student weeks of training in branch	25,000
k(47)	Annual student weeks of training in department	75,000
k(48)	Annual student weeks of training in school	375,000
k(35)	Instructor/Supervisor hours required per month per course	63
k(36)	Instructor/Supervisor hours required per month per entry group	19
k(37)	Instructor/Supervisor hours required per month per student	0.6
k(38)	Instructor/Supervisor hours required per month per shift	41.3
k(39)	Instructor/Supervisor hours required per month per instructor	2.4
k(63)	Instructors and Supervisors fraction officers	0.0
k(64)	Instructors and Supervisors fraction airmen	0.63
k(49)	Curriculum manpower required per branch	4.7
k(50)	Curriculum manpower required per department	4.5
k(65)	Curriculum manpower fraction officers	0.0
k(66)	Curriculum manpower fraction airmen	0.63
k(51)	Training aids maintenance manpower required in branch	11
k(67)	Training aids maintenance manpower fraction officers	0.02
k(68)	Training aids maintenance manpower fraction airmen	0.72
k(52)	Media maintenance manpower required per course	5*
k(69)	Media maintenance manpower fraction officers	0.0
k(70)	Media maintenance manpower fraction airmen	0.0
k(53)	Branch administration manpower required per course	2.3
k(54)	Branch administration manpower required per permanent party course manpower	0.025
k(55)	Department administration manpower required per course	0.07
k(56)	Department administration manpower required per department	22
k(57)	Department administration manpower required per entry group	0.019
k(58)	Department administration manpower required per student	0.003
k(59)	School administration manpower required per school	314
k(71)	Training administration manpower fraction officers	0.06
k(72)	Training administration manpower fraction airmen	0.39
k(60)	Indirect manpower required per school	847
k(61)	Indirect manpower required per total direct manpower	0.12
k(62)	Indirect manpower/total military direct manpower	0.08
k(73)	Indirect manpower fraction officers	0.05
k(74)	Indirect manpower fraction airmen	0.38

SOURCE: Variable names and values from Allison, 1970, except those starred.

Table 16

VARIABLES DETERMINED FROM MANPOWER CALCULATIONS

Instructors for Academies

e(100)	Officers
e(101)	Airmen
e(102)	Military
e(103)	Civilian
e(14)	Total

Instructor and Course Supervisor

e(104)	Officers
e(105)	Airmen
e(106)	Military
e(107)	Civilian
e(15)	Total

Instructors and Supervisors

e(108)	Officers
e(109)	Airmen
e(110)	Military
e(111)	Civilian
e(16)	Total

Curriculum Manpower

e(112)	Officers
e(113)	Airmen
e(114)	Military
e(115)	Civilian
e(22)	Total

Training Aids, Mtc. Manpower

e(116)	Officers
e(117)	Airmen
e(118)	Military
e(119)	Civilian
e(23)	Total

Media Maintenance Manpower

e(120)	Officers
e(121)	Airmen
e(122)	Military
e(123)	Civilian
e(53)	Total

Training Administration Manpower

	Fixed	*Variable*	*Total*
Officers	e(152)	e(156)	e(160)
Airmen	e(153)	e(157)	e(161)
Military	e(154)	e(158)	e(162)
Civilian	e(155)	e(159)	e(163)
Total	e(30)	e(31)	e(32)

Direct Manpower, Including Students

	Fixed	*Variable*	*Total*
Officers	e(164)	e(168)	e(171)
Airmen	e(165)	e(169)	e(172)
Military	e(50)	e(51)	e(173)
Civilian	e(166)	e(170)	e(174)
Total	e(167)	e(43)	e(175)

Indirect (BOS) Manpower

	Fixed	*Variable*	*Total*
Officers	e(176)	e(180)	e(184)
Airmen	e(177)	e(181)	e(185)
Military	e(178)	e(182)	e(186)
Civilian	e(179)	e(183)	e(187)
Total	e(44)	e(45)	e(46)

Total Permanent Party Manpower

	Fixed	*Variable*	*Total*
Officers	e(188)	e(192)	e(196)
Airmen	e(189)	e(193)	e(197)
Military	e(190)	e(194)	e(198)
Civilian	e(191)	e(195)	e(199)
Total	e(47)	e(48)	e(49)

Total Manpower

	Fixed	*Variable*	*Total*
Officers	e(188)	e(192)	e(196)
Airmen	e(189)	e(200)	e(202)
Military	e(190)	e(201)	e(203)
Civilian	e(191)	e(195)	e(199)
Total	e(47)	e(41)	e(42)

On the next several pages are the estimates of cost and manpower made for the example course in summary form. Following the summary is a detailed description of how each estimate was made.

Tables 17 and 18 summarize the number of personnel required to conduct and support the example course. It is estimated that, with an average student load of 100, 126 permanent party personnel will be required. Based on Air Training Command data, these have been divided by function and between military and civilian personnel. Those positions that can be expected to vary with student load have also been separately identified. The total permanent party people are split evenly between military and civilians. The fixed component makes up about 16 percent of the total and consists mostly of civilians in administration and indirect or base operating support. There are 59 instructors and 5 supervisors, 40 of them military airmen and 24 civilians. Given an average student load of 100, this means that the ratio of instructors to students is approximately 0.6. This may be considered high, but it follows from the strategy and the decision not to make students wait for resources. Direct support, which requires 6 civilians and 2 airmen, is primarily to provide for the maintenance of training aids and communications media, and for continued work on curriculum revision. Including the students, a total of 226 people are involved in the course; 163 are military (3 officers, the rest airmen) and 63 are civilians.

The variable names assigned to manpower-related factors in Table 15 are those used by Allison. They are used here to derive manpower requirements for the atypical course of our example (Table 16).

Instructors

Based on Air Training Command practice, instructors are assumed to be able to work 140 hours per month and to devote 105 hours of that to actual teaching. Usual practice would be, therefore, to inflate the teaching requirement by the ratio

$$140 \div 105 = 1.33.$$

In the example, however, the maximum number of instructors required is 59. During the 9000 minutes simulated, these 59 instructors had 6022 encounters with students, each lasting 67.5 minutes. Each instructor is actually involved in teaching

Table 17

SUMMARY OF ESTIMATED MANPOWER REQUIREMENTS

Function	Fixed					Variable					Total				
	Off.	Amn.	Total Mil.	Civ.	Total	Off.	Amn.	Total Mil.	Civ.	Total	Off.	Amn.	Total Mil.	Civ.	Total
Students	--	--	--	--	--	--	100	100	--	100	--	100	--	--	100
Permanent party															
Administration	--	3	3	5	8	--	1	1	1	2	--	4	4	6	10
Instructors and supervisors	--	--	--	--	--	--	40	40	24	64	--	40	40	24	64
Direct support	--	--	--	--	--	--	2	2	6	8	--	2	2	.6	8
Indirect BOS	1	4	5	7	12	2	10	12	20	32	3	14	17	27	44
Total permanent party	1	7	8	12	20	2	53	55	51	106	3	60	63	63	126
Total manpower (including students)	1	7	8	12	20	2	153	155	51	206	3	160	163	63	226

Table 18

MANPOWER TOTALS

DIRECT MANPOWER, INCLUDING STUDENTS

Fixed Component

Officers	e(164) = e(152)	= 0
Airmen	e(165) = e(153)	= 3
Military	e(50) = e(154)	= 3
Civilians	e(166) = e(155)	= 5
Total	e(167) = e(30)	= 8

Variable Component

Officers	e(168) = e(108) + e(112) + e(116) + e(120) + e(156)	= 0
Airmen	e(169) = e(109) + e(113) + e(117) + e(121) + e(157) + d(57,1)	= 143
Military	e(51) = e(168) + e(169)	= 143
Civilians	e(170) = e(111) + e(115) + e(119) + e(123) + e(159)	= 31
Total	e(43) = e(50) + e(170)	= 174

Fixed plus Variable = Total

Officers	e(171) = e(164) + e(168)	= 0
Airmen	e(172) = e(165) + e(169)	= 146
Military	e(173) = e(171) + e(172)	= 146
Civilians	e(174) = e(166) + e(170)	= 36
Total	e(175) = e(173) + e(174)	= 182

INDIRECT MANPOWER

Fixed Component

Officers	e(176)	= 1
Airmen	e(177)	= 4
Military	e(178)	= 5
Civilians	e(179)	= 7
Total	e(44)	= 12

Variable Component

Officers	e(180)	= 2
Airmen	e(181)	= 10
Military	e(182)	= 12
Civilians	e(183)	= 20
Total	e(45)	= 32

Fixed plus Variable = Total

Officers	e(184) = e(176) + e(180)	= 3
Airmen	e(185) = e(177) + e(181)	= 14
Military	e(186) = e(184) + e(185)	= 17
Civilians	e(189) = e(179) + e(183)	= 27
Total	e(46) = e(186) + e(187)	= 44

Table 18--Continued

TOTAL MANPOWER

Fixed Component

Officers	e(188)	= e(164) + e(176)	= 1
Airmen	e(189)	= e(165) + e(177)	= 7
Military	e(190)	= e(188) + e(189)	= 8
Civilians	e(191)	= e(166) + e(179)	= 12
Total	e(47)	= e(190) + e(191)	= 20

Variable Component

Officers	e(192)	= e(168) + e(180)	= 2
Airmen	e(200)	= e(169) + e(181)	= 153
Military	e(201)	= e(192) + e(200)	= 155
Civilians	e(195)	= e(170) + e(183)	= 51
Total	e(41)	= e(201) + e(195)	= 206

Fixed plus Variable = Total

Officers	e(196)	= e(188) + e(192)	= 3
Airmen	e(202)	= e(189) + e(200)	= 160
Military	e(203)	= e(196) + e(202)	= 163
Civilians	e(199)	= e(191) + e(195)	= 63
Total	e(42)	= e(203) + e(199)	= 226

PERMANENT PARTY MANPOWER, NO STUDENTS

Fixed Component

Officers	e(188) =		= 1
Airmen	e(189) =		= 7
Military	e(190) =		= 8
Civilians	e(191) =		= 12
Total	e(47) =		= 20

Variable Component

Officers	e(192) =		=	= 2
Airmen	e(193) =	e(200) - d(57,1)	= 153 - 100	= 53
Military	e(194) =	e(192) + e(193)	=	= 55
Civilians	e(195) =		=	= 51
Total	e(48) =	e(194) + e(195)	=	= 106

Fixed plus Variable = Total

Officers	e(196) =		=	= 3
Airmen	e(197) =	e(189) + e(193)	= 7 + 53	= 60
Military	e(198) =	e(196) + e(197)	=	= 63
Civilians	e(199) =		=	= 63
Total	e(49) =	e(198) + e(199)	=	= 126

$$\frac{6022 \times 67.5}{59} = 6890 \text{ minutes}$$

out of 9000. This ratio,

$$9000 \div 6890 = 1.31,$$

is considered sufficiently close to 1.33 that no additional instructors will be needed. Using the input values from Table 15, we therefore have

Officers	$e(100) = k(63) \times 59$	$= (0.0) \times 59$	$= 0$
Airmen	$e(101) = k(64) \times 59$	$= (0.63) \times 59$	$= \underline{37}$
Military	$e(106) = e(100) + e(101)$	$=$	$= \overline{37}$
Civilians	$e(103) = [1 - k(63) - k(64)] \times 59$	$= (1 - 0.0 - .63) \times 59$	$= \underline{22}$
Total	$e(14) = e(102) + e(103)$	$=$	$= \underline{\underline{59}}$

Instructor Plus Course Supervisors

Total

$$e(15) = \frac{k(35) + e(2) \times d(36) + d(57,1) \times k(37) + k(4) \times k(38) + e(14) \times k(39)}{k(23)}$$

$$e(15) = \frac{63 + 20 \times 19 + 100 \times 0.6 + 1 \times 41.3 + 59 \times 2.4}{140} = 4.9 \longrightarrow 5$$

Officers	$e(104) = k(63) \times e(15)$	$= (0.0) \times 5$	$= 0$
Airmen	$e(105) = k(64) \times e(15)$	$= (0.63) \times 5$	$= \underline{3}$
Military	$e(106) = e(104) + e(105)$	$=$	$= \overline{3}$
Civilians	$e(107) = [1 - k(63) - k(64)] \times e(15)$	$= [1 - 0.0 - .63] \times 5$	$= \underline{2}$
Total	$e(15) =$	$=$	$= \underline{\underline{5}}$

Instructors Plus Supervisors

Officers	$e(108) = e(100) + e(104)$	$= 0 + 0 = 0$
Airmen	$e(109) = e(101) + e(105)$	$= 37 + 3 = \underline{40}$
Military	$e(110) = e(102) + e(106)$	$= 37 + 3 = \overline{40}$
Civilians	$e(111) = e(103) + e(107)$	$= 22 + 2 = \underline{24}$
Total	$e(16) = e(14) + e(15)$	$= 59 + 5 = \underline{\underline{64}}$

Curriculum Manpower

Curriculum manpower is found at both the branch and department levels in Air Force technical training schools. It is estimated that, at the school where the example course is to be taught, there are 5 curriculum developers in each location. They support more courses than ours, so an allocation based on annual student weeks of training must be made. We assume that one department has 3 branches, and each branch conducts 5 courses, each with 5000 annual student-weeks of training. Therefore, total curriculum manpower for our course is given by:

$$e(22) = \left[\frac{k(49)}{k(46)} + \frac{k(50)}{k(47)}\right] e(21) = \left[\frac{4.7}{25,000} + \frac{4.5}{75,000}\right] 5,000 = 1.24 \longrightarrow 1.$$

Officers	e(112)	= k(65) × e(22)	= (0.0) × 1		= 0
Airmen	e(113)	= k(66) × e(22)	= (0.63) × 1		= 1
Military	e(114)	= e(112) + e(113)	=		= 1
Civilians	e(115)	= [1 - k(65) - k(66)] × e(22)	= [1 - 0.0 - .63)] × 1		= 0
Total	e(22)	= e(114) + e(115)	=		= 1

Training Aids Maintenance Manpower

These people are found at branch level, and their time must be allocated to each of the 5 courses in the branch. As above, annual student weeks of training is used as a basis for making the allocation. It has been assumed that 11 people are required to support the branch.

$$\text{Total} \quad e(23) = \frac{k(51)}{k(46)} \times e(21) = \frac{11 \times 5,000}{25,000} = 2.2 \longrightarrow 2$$

Officers	e(116)	= k(67) × e(23)	= (.02) × 2	= 0
Airmen	e(117)	= k(68) × e(23)	= (.72) × 2	= 1
Military	e(118)	= e(116) + e(117)	=	= 1
Civilians	e(119)	= [1 - k(67) - k(68)] × e(23)	= [1 - .02 - .72] × 2	= 1
Total	e(23)	= e(118) + e(119)	=	= 2

Media Maintenance Manpower

These people would also be found at the branch level and be apportioned among the courses supported by that branch. As no data for estimating the requirements for media maintenance workers have been collected, it has been arbitrarily assumed that 5 civilians will be required to support the example course alone.

Training Administration Manpower, Fixed Component

Training administration manpower exists at school, department, and branch levels. The fixed and variable components are estimated separately.

Branch administration is estimated at k(53) persons per course, while both department and school administration people are prorated to the example course on the basis of total annual student weeks.

$$e(30) = k(53) + k(55) + e(21) \times \left[\frac{k(56)}{k(47)} + \frac{k(59)}{k(48)}\right],$$

$$e(30) = 2.3 + .07 + 5,000 \left[\frac{22}{75,000} + \frac{314}{375,000}\right],$$

$$e(30) = 8.$$

Officers	$e(152)$	$= k(71) \times e(30)$	$= (.06) \times 8$	$= 0$
Airmen	$e(153)$	$= k(72) \times e(30)$	$= (.39) \times 8$	$= 3$
Military	$e(154)$	$= e(152) + e(153)$	$=$	$= 3$
Civilians	$e(155)$	$= [1 - k(71) - k(72)] \times e(30)$	$= (.55) \times 8$	$= 5$
Total	$e(30)$	$= e(154) + e(155)$	$=$	$= 8$

Training Administration Manpower, Variable Component

These people are found only at department and branch levels. At branch level they are estimated as a function of the number of instructors and supervisors assigned to the course, and at department level as a function of number of entry groups and average student load

$$e(31) = k(54) \times e(16) + k(57) \times e(2) + k(58) \times d(57.1),$$

$$e(31) = (0.025) \times (64) + (0.019) \times (20) + (0.003) \times (100),$$

$$e(31) = 2.28 \longrightarrow 2.$$

Officers	$e(156)$	$= k(71) \times e(31)$	$= (.06) \times 2$	$= 0$
Airmen	$e(157)$	$= k(72) \times e(31)$	$= (.39) \times 2$	$= 1$
Military	$e(158)$	$= e(156) + e(157)$	$=$	$= 1$
Civilians	$e(159)$	$= [1 - k(71) - k(72)] \times e(31)$	$= (.55) \times 2$	$= 1$
Total	$e(31)$	$= e(158) + e(159)$	$=$	$= 2$

Training Administration Manpower, Total

Officers	$e(160)$	$= e(152) + e(156)$	$= 0 + 0$	$= 0$
Airmen	$e(161)$	$= e(153) + e(157)$	$= 3 + 1$	$= 4$
Military	$e(162)$	$= e(154) + e(158)$	$= 3 + 1$	$= 4$
Civilians	$e(163)$	$= e(155) + e(159)$	$= 5 + 1$	$= 6$
Total	$e(32)$	$= e(30) + e(31)$	$= 8 + 2$	$= 10$

Indirect Manpower, Fixed Component

$$e(44) = \frac{k(60)}{k(48)} \times e(21) + k(61) \times e(30) + k(62) \times e(50),$$

$$e(44) = \frac{847}{375{,}000} \times 5{,}000 + (0.12) \times (8) + (0.08) \times (3),$$

$$e(44) = 12.49 \longrightarrow 12.$$

Officers	$e(176)$	$= k(73) \times e(44)$	$= (.05) \times 12$	$= 1$
Airmen	$e(177)$	$= k(74) \times e(44)$	$= (.32) \times 12$	$= 4$
Military	$e(178)$	$= e(176) + e(177)$	$=$	$= 5$
Civilians	$e(179)$	$= [1 - k(73) - k(74)] \times e(44)$	$= (.63) \times 12$	$= 7$
Total	$e(44)$	$= e(178) + e(179)$	$=$	$= 12$

Indirect Manpower, Variable Component

$$e(45) = k(61) \times e(43) + k(62) \times e(51),$$

$$e(45) = (.12) \times (174) + (.08) \times 143,$$

$$e(45) = 32.32 \longrightarrow 32.$$

Officers	e(180)	= k(73) × e(45)	= (.05) × 32	= 2
Airmen	e(181)	= k(74) × e(45)	= (.32) × 32	= 10
Military	e(182)	= e(180) + e(181)	=	= 12
Civilians	e(183)	= [1 - k(73) - k(74)] × e(45)	= (.63) × 32	= 20
Total	e(45)	= e(182) + e(183)	=	= 32

BASE FACILITIES

Base facilities include the facilities required to carry out the teaching program, plus all real property, exclusive of land, necessary to house the personnel associated with the example course. Current construction costs vary widely both among different types of facilities and for any given type of facility. A gross analysis led to the conclusion that the variation one way was as great as it was the other; hence we used an overall average obtained strictly by observation. It is intended that this number include the entire cost of a facility and everything permanently attached to it--all plumbing, wiring, air conditioning, heating, masonry and other items of general fabrication. An estimate of $20 per square foot, which is an average of current construction costs for a wide range of different kinds of buildings, has been applied throughout.

Estimates of the square footage required were made in a number of different ways, depending on the type of facility for which the estimate was required. For example, the area for the general carrel facility was based on the size of the carrels and chairs themselves and the number required. A generous amount was allowed for access and free space. Storage facility space was estimated from the cubage of the items to be stored, translated into area requirements.

The estimates of space for officer and airman family housing assume an average family size and the fact that some fraction of the military personnel will live off base, some who are unmarried and live on base will live in barracks or the BOQ, while married personnel living on base will be provided with family housing. None of these proportions are stated explicitly, but all are inherent in the estimate.

Office space for instructors, supervisors, and administrators has been allocated, based on assumed rank and responsibility. For example, the administrators have been provided with individual offices of 100 square feet each, while two airman instructors are assigned to the same size office.

The costs of facilities are summarized on Table 19. Total investment in facilities estimated for the example course is approximately $1.5 million, of which $1 million is for on-base permanent party military personnel housing and almost $0.3 million is for student housing. Students live in dormitories, two in a 15 × 15 foot room, not in open barracks. Twenty-five percent of the living space in the student dormitories is provided for commons rooms, recreational areas, and study areas. Office space accounts for approximately $0.1 million, and the remaining $0.1 million provides for tutoring rooms, discussion rooms, darkrooms, maintenance shops, and other special-purpose facilities.

Table 19

SUMMARY OF ESTIMATED FACILITIES COST

	Cost
Investment	
Tutoring space	$ 30,000
Discussion space	30,000
Office space	110,000
Paper-and-pencil testing area	8,800
Carrel area (including storage)	23,280
Darkrooms	10,500
Training aids and media hardware maintenance shop	8,000
Permanent party military personnel on-base housing	990,000
Student housing—dormitories	281,250
Subtotal	$1,491,830
Utilities—assume included in $20 per square foot	---
Total facilities investment cost	$1,491,830
Initial Stocks	
Facilities maintenance materials	$ 2,500
Annual Operating	
Facilities replacement	$ 74,591
Maintenance	15,000
Total facilities operating cost	$ 89,591

Below, each of the relevant assumptions is made explicit.

Investment

Tutoring rooms are needed for 12 student-instructor pairs. Assume 100 square feet per pair, plus 25 percent for accessways, lavatories, coffee rooms, supply rooms, etc. Therefore, *Initial Cost of Tutoring Rooms*

$$100 \times 12 \times 1.25 \times \$20 = \$30{,}000.$$

Discussion rooms are needed for 12 student-instructor pairs. Using the same assumptions as above,

Initial Cost of Discussion Rooms

$$\$30{,}000.$$

Assume office space for

59	instructors	@ 50 square feet
5	supervisors	@ 75 square feet
1	curriculum developer	@ 75 square feet
10	administration	@ 100 square feet

and assume 25 percent for accessways, lavatories, coffee rooms, supply rooms, etc. Therefore,

Initial Cost of Office Space

$$[(59 \times 50) + (5 \times 75) + (1 \times 75) + (10 \times 100)]$$

$$\times 1.25 \times \$20 = \$110{,}000.$$

Paper-and-pencil testing space is needed for 20 students and 1 supervisor. Assume open classroom space with a desk for the supervisor and student chairs with arms suitable for writing on. Therefore, allocate for

1	supervisor	@ 20 square feet
20	students	@ 10 square feet

and assume 100 percent for clearance between chairs, storage space, etc. Therefore,

Initial Cost of Testing Area

$$[(1 \times 20) + (20 \times 10)] \times 2.0 \times \$20 = \$8{,}800.$$

Carrel area space is needed for 55 carrels and storage for media hardware and software. Assume a carrel occupies 8 square feet and, with chair, 12 square feet. Add 50 percent for walkways and general access. Therefore, *Carrel Space*

$$(55 \times 12) \times 1.5 \times \$20 = \$19{,}800.$$

Storage room is also needed for:

Portable Media Hardware	
Sound-motion film viewers	11
Silent-motion film viewers	8
Sound-slide set projectors	19
Class V teaching machines	28
Total items	66[a]
Media Software[b]	
Sound-motion films	11
Silent-motion films	10
Sound-slide sets	27
Class V teaching machine programs	46
Total copies	94

[a]Rounded to 75.

[b]Because we were more likely to accumulate extra copies of software, a larger safety factor was provided, allowing space for 200 items.

Assume each item of hardware requires 3.375 cubic feet and each item of software 0.25 cubic feet. Add 15 percent for hardware and 10 percent for software to cubage; therefore, we shall need

$$(75 \times 3.375 \times 1.15) + (200 \times .25 \times 1.1) = 346 \text{ cubic feet.}$$

If these are stored on shelves or in bins no more than 6 feet high, we shall require

$$346 \div 6 = 58 \text{ square feet for storage alone.}$$

Increase this by 3 for access, handling, and room for expansion. Therefore,

$$58 \times 3 \times \$20 = \$3{,}480.$$

Therefore, for the total carrel and storage area we have:

Initial Cost of Carrel Space

Carrel area	$19,800
Storage area ...	3,480
Total	$23,280

Darkrooms are needed for 14 students. Assume 1 student per darkroom, which is 30 square feet. Add 25 percent for access. Therefore,

Initial Cost of Darkrooms

$$14 \times 30 \times 1.25 \times 20 = \$10,500.$$

Assume 20 × 20 or 400 square feet sufficient for training aids and media hardware maintenance shop. Therefore,

Initial Cost of Maintenance Shop

$$400 \times 20 = \$8,000.$$

Housing is needed for 3 officers and 60 airmen permanent party personnel (on base). Assume 1500 square feet per officer and family and 750 square feet per enlisted man and family. Therefore,

Initial Cost of Housing

$$[(3 \times 1500) + (60 \times 750)] \times \$20 = \$1,990,000.$$

Dormitories are needed for 100 students. Assume 2 students per room and each room 15 × 15 or 225 square feet. Add 25 percent for commons rooms, recreational, and study space. Therefore,

Initial Cost of Dormitories

$$\frac{100}{2} \times 225 \times 1.25 \times \$20 = \$281,250.$$

Initial Stocks

Initial stocks of facilities maintenance materials:

$$\text{60 days' supply} = \frac{15,000^{*} \times 2}{12} = 2,500.$$

---

*See annual cost of maintenance materials, below.

Annual Operating

All facilities are assumed to have a 20-year useful life; an annual replacement cost equal to 5 percent of the initial cost is charged to cover this requirement. Therefore,

$$.05 \times \$1,491,830 = \$74,591.$$

All regular maintenance on the facilities is performed by base operating support personnel whose pay is included under annual pay and allowances. However, the cost of materials for this purpose, estimated at 1 percent of total investment, is a separate annual cost amounting to $15,000.

ANNUAL UTILITIES

This category includes the primary cost of electric power, along with gas for heating and cooking. It is assumed that these products are purchased from commercial sources. Water supply is not included here, as it is assumed that the base owns and operates its own water supply and therefore the cost of water is covered in the various base operating support costs. Gas and electricity are estimated to cost annually $75 per military man, including students, plus $50 , r civilian:

$$(\$75 \times 163) + (\$50 \times 63) = \$15,375.$$

MEDIA HARDWARE

According to the requirement that students not wait for either media hardware or software, we purchase initially enough to meet the maximum number of units that will ever be demanded simultaneously. Because not all units of hardware will be in use at one time for a significant portion of the time, they will be available for preventive and corrective maintenance sufficiently often so that extra units will not need to be purchased for this purpose.

Three costs are of concern: (1) the initial purchase cost, (2) an annual cost to provide for depreciation or wearout and eventual replacement, and (3) an annual cost of replacement parts and maintenance materials. The wearout rate is based on an estimate of the number of times each type of hardware can be used, assuming an average 20 minutes per use. A summary of the requirements for media hardware follows:

Item	Maximum Requirement[a]	Uses in 9000 Minutes[a]	Uses per Year[b]
Sound-motion film viewers	11	331	2,648
Silent-motion film viewers	8	663	5,304
Sound-slide set projectors	19	1,327	10,616
Class V teaching machines	28	1,997	15,976

[a]Outputs from simulation model.

[b]9000 minutes is the equivalent of 9000 ÷ 2785 minutes per course or 3.23 courses. In one year there will be 26 courses (at 2 weeks per course). Therefore, uses from the simulation model must be inflated by the ratio 26/3.23 = 8.

The following cost factors and wearout rates apply:

Item	Initial Cost (each)	Replacement Parts (per year/unit)	Useful Life (uses)
Sound-motion film viewers	350	25	5000
Silent-motion film viewers	150	12	5000
Sound-slide set projectors	150	12	4000
Class V teaching machines	200	15	3000

In addition to the annual cost of replacement parts (maintenance materials), an initial stock level equal to two months' requirements will be purchased and maintained. The cost of maintenance labor is covered in the personnel supplied for this purpose and their costs.

Media hardware costs are summarized in Table 20. Table 21 gives the details on which these are based.

SOFTWARE

Software is divided into two categories: (1) display media such as film, slides, and teaching machine programs, and (2) printed media such as texts, workbooks, lesson guides, and evaluation guides.

In the first category, each item is related to a single learning event, and the number required depends on the maximum demand, which is determined by the student flow simulation model. The initial cost of these items includes the cost of producing a master and the required number of copies and of packaging the copies. All packages such as cassettes, reels, magazines, etc., are assumed to have an infinite

Table 20

SUMMARY OF ESTIMATED MEDIA HARDWARE COSTS

(In dollars)

Item	Sound-Motion Film Viewers	Silent-Motion Film Viewers	Sound-Slide Set Projectors	Class V Teaching Machines	Maint. Equip.[a]	Total
Investment						
Equip. purchase	3,850	1,200	2,850	5,600	---	13,500
Maint. materials, stocks & equip.	46	16	38	70	1,000	1,170
Total	3,896	1,216	2,888	5,670	1,000	14,670
Operating						
Maint. materials	275	96	228	420	200	1,219
Equip. replacement	185	159	398	1,065	---	1,087
Total	400	255	626	1,485	200	3,026

[a]Estimate of equipment for media maintenance shop.

life. Producing the master includes a certain amount of script writing, all editing, and the use of all necessary equipment. All of this production is handled on a contract basis.

Each year, as specified in the curriculum analysis, each master undergoes some revision. When the curriculum analysis calls for complete revision in 60 months, cost estimates are made based on revising 20 percent each year. Revisions are made to the master copy, after which a complete set of new copies is prepared and the old ones are discarded. The master copy is never used by the students. In addition to the new set of copies made each year, some extras are required to replace those lost, damaged, or worn out through normal usage. However, this sort of replacement requires only the copying of the master.

The largest element of cost is associated with the initial preparation and subsequent revision of the masters. Making copies costs relatively little.

In the second category--texts, workbooks, lesson and evaluation guides--the following assumptions have been made: Each student and instructor is provided with a copy of each text and workbook, and each instructor with lesson and evaluation guides also. Although these items

Table 21

DETAILS OF MEDIA HARDWARE COSTS

	Cost ($)
Sound-Motion Film Viewers	
Initial costs	
Purchase of 11 viewers @ $350	3,850
Initial stocks of maintenance materials	46
46 = ($25 × 11 units) ÷ 6	
Annual costs	
Replacement (2648 uses/5000 uses) × $350	185
Maintenance materials ($25 × 11 units)	275
Silent-Motion Film Viewers	
Initial costs	
Purchase of 8 viewers @ $150	1,200
Initial stock of maintenance materials	16
16 = ($12 × 8 units) ÷ 6	
Annual costs	
Replacement (5304 uses/5000 uses) × $150	159
Maintenance materials ($12 × 8 units)	96
Sound-Slide Set Projectors	
Initial costs	
Purchase of 19 projectors @ $150	2,850
Initial stock of maintenance materials	38
38 = ($12 × 19 units) ÷ 6	
Annual costs	
Replacement (10,616 uses/4000 uses) × $150	398
Maintenance materials ($12 × 19 units)	228
Class V Teaching Machines	
Initial costs	
Purchase of 28 machines @ $200	5,600
Initial stock of maintenance materials	70
70 = ($15 × 28 units) ÷ 6	
Annual costs	
Replacement (15,976 uses/3000 uses) × $200	1,065
Maintenance materials ($15 × 28 units)	420

are considered expendable and hence an annual cost, a 6-month supply of student material is procured initially and maintained in a stock at all times. The major cost items are the initial preparation of programmed text material and its annual revision. The annual consumption of expendable material is also significant.

Costs of software are summarized in Table 22.

Films, Slides, and Teaching Machine Programs

Three separate costs are estimated: (1) the initial investment in the master and in the required number of prints, (2) the annual cost of revisions due to change in content, and (3) the annual cost of replacement due to damage or normal wearout. For films and slides, the practice is to make a master, use it to make prints, but not make it available to students. Revisions are made to the master annually and all copies are remade. This results in a complete new set of software each year. However, due to normal usage, additional replacement copies may be required. If so, an additional cost of making copies from the master is incurred. All cartridges are assumed to have an infinite life and thus are purchased once and reused.

The following formulas were applied to compute the cost of initial investment, I(1), annual revision, A(1), and annual replacement, A(2).

$$I(1) = x(16)[f(3) + f(4) \times C(1)] + \left(\text{integer part of: } \left[\frac{x(16)}{f(6)} + .9\right]\right) \times [1 + C(1)] \times f(5).$$

The terms on the second line are not applicable to teaching machine programs.

$$A(1) = x(16)\left[\frac{12f(3)}{x(20)} + f(4) \times C(1)\right]$$

$$A(2) = x(16) \times f(4)\left[\frac{52d(57,1)}{2f(1)} - C(1)\right]$$

where d(57,1) = average student load

C(1) = number of copies required

x(16) = number of minutes of product required

x(20) = number of months between revisions

Table 22

SUMMARY OF COSTS OF SOFTWARE

	Initial Cost	Annual Cost
NON-PRINT MEDIA		
Initial Investment		
Sound-motion film	$ 94,410	
Silent-motion film	44,395	
Sound-slide sets	10,720	
Class V teaching machine programs	16,275	
Total	$165,800	
Annual Replacement		
Sound-motion film		$ 0
Silent-motion film		0
Sound-slide sets		60
Class V teaching machine programs		33
Total		$ 93
Annual Revision		
Sound-motion film		$22,734
Silent-motion film		11,688
Sound-slide sets		8,075
Class V teaching machine programs		4,890
Total		$48,387
PRINT MEDIA		
Initial Investment		
Conventional texts	$ 4,116	
Programmed texts	25,808	
Workbooks	2,760	
Texts and workbooks	$ 32,684	
Lesson and evaluation guides	2,765	
Total	$ 35,449	
Annual Consumption		
Conventional texts		$ 7,848
Programmed texts		9,156
Workbooks		5,264
Texts and workbooks		$22,268
Lesson and evaluation guides		14
Total		$22,282
Annual Revision		
Programmed texts		$ 4,200
Lesson and evaluation guides		540
Total		$ 4,740

f(1) = useful life, in number of uses

f(3) = cost per minute for producing master

f(4) = cost per minute for making prints

f(5) = cost of cartridge or slide magazine

f(6) = number of minutes of product per cartridge.

Costs are computed for each type of software for each learning event in which that type is used, since C(1), x(16), and x(20) vary from event to event. For all computations, however, d(57,1) = 100. Results of these computations are shown in Table 23.

Texts, Workbooks, and Guides

A conventional (off-the-shelf) text, a programmed (specially prepared) text, and a workbook will be used in the basic photography course. A complete set of these will be provided to each student when he enters the course, and they will be his to take with him when he leaves.

Each instructor and course supervisor will also be given a complete set of the texts and workbooks. The text material provided to the instructors will be replaced at a rate of 25 percent per year.

A stock level of all printed matter equal to a 6-months' supply will be maintained at all times. Table 22 summarizes the investment and operating costs of these materials.

The basic text is a standard text on elementary photography. In quantity, they are estimated to cost $3.00 each. Therefore, we have

Annual student throughput	2600
One text per student @	× $3
Cost of annual consumption of conventional texts (students)	$7800
Number of instructors and supervisors	64
One text per instructor per 4 years = $3/4 per instructor per year	×$.75
Cost of annual consumption of conventional texts per instructor	$48
Annual cost of conventional texts	
Students	$7800
Instructors	48
Total	$7848
Initial stock level of conventional texts	
Students @ 1/2 annual consumption	$3900
Instructors' initial requirement plus 1/2 annual consumption	216*
Total	$4116

*64 × 3 + .5 × 48 = 216.

Table 23

COMPUTATION OF COST OF FILMS, SLIDES, AND TEACHING MACHINE PROGRAMS

Medium and Fixed Values	Event Number	Event-Dependent Values			Costs ($)		
		C(1)	x(16)	x(20)	I(1)	A(1)	A(2)
Sound-motion film f(1) = 500, f(15) = $15 f(3) = $988, f(6) = 30 f(4) = $5	1,3	11	90	60	94,410	22,734	0
Silent-motion film f(1) = 500, f(5) = $10 f(3) = $790, f(6) = 30 f(4) = $3	2,3	5	30	48	24,210	6,375	0
	4,3	5	25	60	20,185	5,313	0
Totals					44,395	11,688	0
Sound-slide sets f(1) = 500, f(5) = $3 f(3) = $70, f(6) = 27 f(4) = $5	1,1	11	25	12	3,161	3,125	0
	3,5	8	50	24	5,554	3,750	0
	3,12	3	6	24	562	300	60
	7,3	5	15	24	1,443	900	0
Totals					10,720	8,075	60
Class V teaching machine programs f(1) = 200, f(5) = -- f(3) = 60, f(6) = -- f(4) = .03	1,2	11	60	24	3,620	1,820	5
	1,4	10	50	60	3,015	615	5
	2,1	6	20	60	1,204	244	4
	2,2	10	100	60	6,030	1,230	9
	4,1	4	15	48	902	227	4
	6,2	5	25	24	1,504	754	6
Totals					16,275	4,890	33

The programmed text is prepared especially for this course, based on the requirements stated in the curriculum and shown in the expanded curriculum analysis. The following learning events and average times apply (see Table 12):

Lesson	Learning Event	Average Time (minutes) = x(16)
3	1	30
3	2	50
3	3	25
3	6	50
3	8	35
4	4	15
5	1	75
5	3	30
6	1	27
Total		337[a]

[a]Which we compute as 350 min.

One page of programmed text is assumed to be equal to one minute of study and to cost \$60 to produce. Once the offset prints have been made, copies can be printed for \$0.01 per page. It is also assumed that 20 percent of the material contained in the programmed text will be revised annually, at 20 percent of the initial cost of production.

The following were computed:

Cost of initial preparation of offset prints:

350 minutes	=	350 pages
Cost per page	=	×\$60
Total		\$21,000

Cost of copies of programmed texts:

350 minutes	=	350 pages
Cost per page	=	×\$.01
Cost per text	=	\$3.50

Annual cost of revision:

Initial cost of offsets =	\$21,000
Revise 20 percent	×.2
Total	\$ 4,200

Cost of annual consumption of programmed texts (students):

Annual student throughput	2600
One text per student @	×\$3.50
Total	\$9100

Cost of annual consumption of programmed texts (instructors):

Number of instructors and supervisors	64
One text per instructor per 4 years = \$3.50/4	
per instructor per year	×\$.875
Total	\$ 56

Total annual cost of programmed texts:

Students	\$ 9,100
Instructors	56
Revision	4,200
Total	\$13,356

Initial cost of programmed texts:

Preparation of offsets	\$21,000
Students @ 1/2 of annual consumption	4,550
Instructors initial requirement	
plus 1/2 annual consumption	252*
Total	\$25,802

*64 × 3.5 + .5 × 56 = 252.

The workbook, a standard supplement to the conventional text, is an off-the-shelf item costing $2.00 per copy. The following was computed:

Annual cost of workbooks (students):

Annual student throughput	2600
One workbook per student @	×$2
Total	$5200

Annual cost of workbooks (instructors):

Number of instructors and supervisors	64
One text per instructor per 4 years = $2/4 per instructor per year	×$1
Total	$64

Total annual cost of workbooks:

Students	$5200
Instructors	64
Total	$5264

Initial cost of workbooks:

Students @ 1/2 annual consumption	$2600
Instructors @ initial requirement plus 1/2 annual consumption	160*
Total	$2760

Lesson and evaluation guides compose a single volume that is prepared specially for this course, based on the requirements stated in the curriculum and shown in the expanded lesson analysis. The following learning events and average times apply.

Type of Guide	Learning Event	Average Time (minutes) x(6)
Lesson	2,4	10
Lesson	3,7	30
Lesson	6,3	49
Evaluation	2,7	15
Evaluation	3,13	36
Evaluation	4,10	12
Evaluation	7,4	128
Evaluation	7,5	30
Total		310[a]

[a]Which we compute as 300 minutes.

*64 × 2 + .5 × 64 = $160.

One page of a lesson or evaluation guide is the equivalent of 3 1/3 minutes of instruction and costs $30 to produce. Once the offset prints are available, copies can be made for $0.01 per page. It is assumed that 20 percent of the material contained will be revised each year, at 20 percent of the cost of initial production.

Cost of initial preparation of offset prints:

300 minutes ÷ 3.33 minutes per page	90
Cost per page	×$30
Total	$2700

Cost of copies of lesson and evaluation guide:

Number of pages per guide	90
Cost per page for copies	×.01
Total	$.90

Annual cost of revisions:

Initial cost of offsets	$2700
Revise 20 percent	×.20
Total	$ 540

Lesson and evaluation guides are for instructor and supervisor use only.

Annual cost of consumption of guides:

Number of instructors and supervisors	64
One guide per instructor per 4 years	
.90/4 per instructor per year	×$.225
Total	$ 14

Total annual cost of guides:

Consumption	$ 14
Revision	540
Total	$554

Initial cost of guides:

Preparation of offsets	$2700
Instructors' initial requirement	
plus 1/2 annual consumption	65*
Total	$2765

---

*64 × .90 + .5 × 14 = $64.60.

TRAINING AIDS AND MATERIALS

Press Camera and Accessories

Enough sets of cameras and accessories must be provided so that all students requiring them at one time will have them. The maximum number can be determined from the simulation run, which shows the maximum number of students in each learning event simultaneously. As cameras are not used in all events, only those for which x(13) = 1 must be considered. Eventually, equipment will be identified in the curriculum analysis. At present, reference to the course outline is necessary; this shows that the only special equipment needed is the camera and accessories. The simulation model shows the maximum number of sets of camera equipment, 18, to be required in learning event 3,9. Two extra sets will be purchased to fill the maintenance pipeline.

Initial Cost:

Purchase 20 units @ $500	$10,000
Initial stocks of maintenance materials	83*

Annual Costs:

Replacement @ 20 percent per year	$2,000
Maintenance materials $25 × 20	500

Darkroom Equipment

Standard darkroom equipment will be provided for each of 14 darkrooms. No enlarging will be required, so equipment for that purpose will not be included.

Initial Cost:

Purchase 14 sets @ $200	$2,800
Initial stocks of maintenance materials	23†

Annual Costs:

Replacement @ 10 percent per year	$280
Maintenance materials @ $10 per unit/year	140

*($25 per unit per year × 20 units) ÷ 6 = $83 (60-day supply).

†($10 per unit per year × 14 units) ÷ 6 = $23 (60-day supply).

Darkroom Supplies

These include film, photographic paper, developer, hypo, stop bath, etc. Each student is allowed $10 per course for these items. A two-month supply is kept on hand at all times.

Initial Cost:

Initial stocks $4,333*

Annual Costs:

Annual consumption: 2600 students @ $10 .... $26,000

Furnishing Teaching Facilities

The cost of furnishing teaching facilities is summarized in the table below. Teaching facilities include: tutoring and discussion

SUMMARY OF TEACHING FACILITY FURNISHING COST

Item	Initial Purchase	Annual Replacement
Tutoring rooms	$ 4,200	$ 420
Discussion rooms	4,200	420
Testing area	2,700	270
General carrel area	7,075	708
Subtotal	$ 18,175	$ 1,818
Miscellaneous personnel-related	652,000	65,200
Total	$670,175	$67,018

rooms where students meet with instructors on a one-to-one basis for basic instruction, formal examination, planned review, or discussion of prior media presentations; a paper-and-pencil testing area; and a general carrel area. These are each described in the section on estimating the initial cost of facilities.

Tutoring and Discussion Rooms

Each room is equipped with the following items:

*(2600 students × $10 per student) ÷ 6 = $4333.

1 desk	$175
1 chair	50
1 chair	25
1 chalkboard	50
1 storage cabinet	50
Total	$350

From the simulation model we find a requirement for 12 tutoring rooms and 12 discussion rooms. Therefore,

Initial Cost:

Tutoring rooms	12 @ $350 = $4,200
Discussion rooms	12 @ $350 = $4,200

It is assumed that this equipment has a ten-year useful life and thus on the average 10 percent will be replaced each year. Maintenance will be so small as to be negligible.

Annual Cost:

Tutoring rooms	12 × 350 × .1 = $420
Discussion rooms	12 × 350 × .1 = $420

<u>Paper-and-Pencil Testing Area and General Carrel Area</u>

The two will be kept separate but similarly furnished. In each there will be:

1 desk for supervisor @ $175
1 chair for supervisor @ $25

For each student

1 carrel @ $100
1 chair @ $ 25

Initial Cost for Furnishing Testing Area (capacity for 20 students):

$200 + $125 × 20 = $2700

Annual Cost for Testing Area:

10 percent of initial cost = $270

Initial Cost for Carrel Area (capacity for 55 students):

$$\$200 + \$125 \times 55 = \$7075$$

Annual Cost for Carrel Area:

10 percent of initial cost = \$708

Personnel-Related Furnishings and Equipment

Included in this category is equipment for non-teaching-related personnel, such as furnishings for living quarters, base vehicles, and other base operating support equipment. Also included are furnishings for student quarters. It is estimated that the initial cost of this equipment would be approximately \$4000 per military man, including students, and the annual cost for replacement would be approximately 10 percent of the initial cost.

Initial Cost:

$$163 \times \$4000 = \$652{,}000$$

Annual Cost:

$$163 \times \$4000 \times .10 = \$65{,}200$$

MILITARY PERSONNEL TRAINING COST

Two kinds of formal training cost are of interest: initial and annual. Initial training cost includes all those training costs necessarily incurred to bring a raw recruit to the level of capability required by the job to which he is assigned. This would include basic training plus any additional specialty training that might be required. Annual training includes similar training costs for personnel added each year to replace those lost through normal turnover. These training costs are relevant to military personnel only, as it is assumed that civilian personnel are hired already having the necessary capabilities.

The following factors are estimates of what these training costs might be and of the turnover rates that might be expected.

Personnel	Training Cost	Turnover Rate (%)
Average officer	$5000	15
Average airman	5000	20
Airman instructor and supervisor	7000	20

Permanent Party Military Personnel	Officers	Airmen
Administration	---	4
Instructors and supervisors	---	40
Direct support	---	2
Indirect BOS	3	14

Therefore, we would have:

Initial Training Cost:

Administrative personnel	4 × $5000	= $ 20,000
Instructors and supervisors	40 × $7000	= 280,000
Direct support	2 × $5000	10,000
Indirect BOS	(3 × $5000) + (14 × $5000)	= 85,000
Total		$395,000

Annual Training Cost:

Administrative personnel	4 × $5000 × .20	= $ 4,000
Instructors and supervisors	40 × $7000 × .20	= 56,000
Direct support	2 × $5000 × .20	= 2,000
Indirect BOS	(3 × $5000 × .15) + (14 × $5000 × .20)	= 17,250
Total		$79,250

STAFF ANNUAL TRAVEL

This relatively small item covers the expense of travel by administrators and instructors to Air Force conferences, possible attendance at professional meetings, field trips for technical research, etc. It is estimated that 10 percent of the staff would take an average of two such trips per year at an estimated cost of $300 per trip. Therefore,

Annual Travel (Staff):

.10 × 74 × 2 × $300 = $4,440

STUDENT TEMPORARY DUTY TRAVEL

Assume we have 100 students per course, with 14 days per course, or 26 courses per year. Assume also that students receive $3.42 per day for TDY. Then,

Annual Travel (Students):

$$100 \times 26 \times 14 \times \$3.42 = \$124,488$$

MISCELLANEOUS PERSONNEL SUPPLIES

This includes a 60-day stock of all non-training personnel supplies, such as food, clothing, fuel, etc. These are all consumables and, as such, are annual cost, except for the 60-day supply maintained in stock at all times. It is estimated that these supplies will cost $200 per military man per year, students included.

Initial Cost:

$$(163 \times \$200) \div 6 = \$5,433$$

Annual Cost:

$$163 \times \$200 = \$32,600$$

GENERAL OFFICE SUPPLIES

Included would be paper, pencils, forms, and the typical complement of general office supplies for use by all administrative and instructor personnel. It is estimated that their cost would amount to $50 per administrator and instructor annually and that a 60-day supply would be maintained in permanent stock.

Initial Cost, Office Supplies:

$$(74 \times \$50) \div 6 = \$617$$

Annual Cost, Office Supplies:

$$74 \times \$50 = \$3,700$$

ANNUAL PAY AND ALLOWANCES

The annual cost of pay and allowances is estimated from a combination of the manpower requirements derived earlier. and the estimates of pay and allowance rates by grade and personnel distribution fractions from Allison, shown in Table 24. The results are summarized in Table 25 and described in detail thereafter.

Table 24

FACTORS FOR ESTIMATING PAY AND ALLOWANCE COST (ALLISON)

Annual Pay and Allowance Rates		
M(30)	Annual pay and allowance cost per student	$ 2,744
M(47)	Annual pay and allowance cost per airman E7	9,754
M(48)	Annual pay and allowance cost per airman E6	8,614
M(49)	Annual pay and allowance cost per airman E5	7,564
M(50)	Annual pay and allowance cost per airman E4	5,737
M(51)	Annual pay and allowance cost per airman E3	3,376
M(57)	Annual pay and allowance cost per average officer	$16,700
M(58)	Annual pay and allowance cost per average airman	6,600
M(54)	Annual pay cost per civilian GS 9	10,560
M(55)	Annual pay cost per civilian GS 7	8,660
M(59)	Annual pay cost per average civilian	8,500
Personnel Distribution Fractions		
M(35)	Airmen instructors and supervisors--fraction E7	.079
M(36)	Airmen instructors and supervisors--fraction E6	.342
M(37)	Airmen instructors and supervisors--fraction E5	.421
M(38)	Airmen instructors and supervisors--fraction E4	.053
M(39)	Airmen instructors and supervisors--fraction E3	.105
M(42)	Civilian instructors and supervisors--fraction GS 9 ..	.182
M(43)	Civilian instructors and supervisors--fraction GS 7 ..	.818

Table 25

SUMMARY OF ANNUAL PAY AND ALLOWANCES

Function	Fixed	Variable	Total
Permanent Party			
Instructors and supervisors	---	$303,424	$ 518,864
Training administration	$ 62,300	15,100	77.400
Curricula	---	6,600	6,600
Training aids maintenance	---	15,100	15,100
Media maintenance	---	42,500	42,500
Base admin. and support	102,600	269,400	372,000
Subtotal	$164,900	$652,124	$1,032,464
Students	---	274,400	274,400
Total annual pay and allowances	$164,900	$926,524	$1,306,864

Instructors and Instructor and Course Supervisors

Military Personnel Airmen by Rank (total = 45)				
Rank	Fraction	Number	Annual P&A/Airman	Total Annual P&A
E7	.079	3	$9,754	$ 29,262
E6	.342	14	8,614	120,596
E5	.421	17	7,564	128,588
E4	.053	2	5,737	11,474
E3	.105	4	3,376	13,504
Total	1.000	40	---	$303,424

Civilian Personnel by Grade (total = 21)				
Grade	Fraction	Number	Annual Pay/Civ.	Annual Pay
GS 9	.182	4	$10,560	$ 42,240
GS 7	.818	20	8,660	173,200
Total	1.000	24	---	$215,440

Summary:

Airmen	$303,424
Civilians	215,440
Total	$518,864

Curricular Manpower:

1 average airman @ $6,600 = $6,600

Training Aids Manpower:

1 average airman	@ $6,600	=	$ 6,600
1 average civilian	@ 8,500	=	8,500
Total			$15,100

Media Maintenance and Support Manpower:

5 average civilians @ $8,500 = $42,500

Fixed Training Administration Manpower:

3 average airmen	@ $6,600	=	$19,800
5 average civilians	@ 8,500	=	42,500
Total			$62,300

Variable Training Administration Manpower:

1 average airman	@ $6,600 =	$ 6,600
1 average civilian	@ 8,500 =	8,500
Total		$15,100

Fixed Indirect Base Administration and Support Manpower:

1 average officer	@ $16,700 =	$ 16,700
4 average airmen	@ 6,600 =	26,400
7 average civilians	@ 8,500 =	59,500
Total		$102,600

Variable Indirect Base Administration and Support Manpower:

2 average officers	@ $16,700 =	$ 33,400
10 average airmen	@ 6,600 =	66,000
20 average civilians	@ 8,500 =	170,000
Total		$269,400

Students:

100 average student airmen @ $2,744 = $274,400

Appendix C

PRELIMINARY DESCRIPTION OF THE STUDENT FLOW MODEL

Margaret G. Samaniego

Following is a more detailed description of the student flow simulation model, a simplified form of which was used in the example case, as discussed in Sec. IV of this report, "Generating Resource Requirements from Student Flow."

Previous work in the area of simulation models of student flow--for example, John F. Cogswell and coauthors, *Analysis of Instructional Systems*, System Development Corporation--has not been programmed to handle resource allocation problems associated with student flow. In other words, the flow in these models is specified in terms of the student and the system, regardless of resource availability. We feel that this is too important a factor to do without.

Another difference from previous student flow models is that the Rand MODIA model is designed for use by nonprogrammers. The course designer can represent a wide variety of educational systems by selecting from a large menu of input options. At the same time, the Rand model is modular enough to satisfy the most innovative and imaginative planner who might want to alter it in some way.

Documentation for the nonprogrammer user is planned to consist of very detailed definitions of input variables, with a specification of the allowable combinations of options, together with a similar description of outputs and their interpretations. It is now planned to have the student population, the course, and any special events completely specifiable by input. The decision rules for movement through the course are to be an integral part of the model, to be selected by the user, rather than provided by him.

Documentation for the user who wishes to reprogram some part of the model would consist of complete flow charting and listing of internal variable definitions and usages, along with suggestions and checklists for expanding or modifying the basic student flow model to include other desired capabilities. One expansion that comes to mind is to simulate students' progress through a total curriculum, involving a number of courses. This could probably be achieved with only slight modifications of the basic model.

It should be noted that, although this report is limited to modeling the flow of students through one course only, there is no reason why a user could not simulate several courses that would be taught concurrently, to examine the effec.s of resource sharing among courses, for instance.

Although the student flow model is part of the entire MODIA system, it can be used without the curriculum analysis questionnaire (R-1020-PR) and/or the instructional strategy decision process described in R-1019-PR. Moreover, although these outputs form the input to the student flow model, the planner has not been removed from the process. The planner may and should alter any items his judgment dictates; it is not necessary to rerun the earlier processes with changed decisions, if he now feels that he wishes to alter some of his original judgments.

A SIMPLE EXAMPLE OF MODEL APPLICATION

The basic elements of the student flow model are (1) the student population, (2) the course, considered as a set of learning events of specified types, (3) the instructional resources, and (4) decision rules for student movement through the course. Here we give perhaps the simplest possible example as a base case, with two slightly more complex alternatives.

The simplest student population would have neither ability nor background characteristics defined for it. Students would arrive in blocks of N students every J time units to start the course. These blocks would move through the course as a single unit.

A simple course would be described by, say, 50 learning events of 3 types: lecture, review, and examination. The media to be used would be different for each type of event. The software type to be used would be different for each type of hardware and the software content would differ for each event. Each event would have a single unique prerequisite event so that there would be but one sequence in which the events could be studied.

A simple decision rule for effecting the students' movement through the course would be to set a fixed rate of progress for each block of students moving through an event. That rate of progress would in fact be identical to the average time associated with each event. Since no characteristics are associated with the students that might affect direction of flow, there would be no decision rule requesting such a variation.

Media types might vary by type of instruction. Depending on the distribution of these types through the learning event sequence, this would have differing effects on the number of students that could be accommodated without a queue *if* there were a limited supply of, for example, media hardware. That is, as the entry rate was parameterized to permit overlapping groups of students to take the course concurrently, possible bottleneck conditions would occur, depending on these factors. This very simple case might be run for the sake of making the following more interesting comparisons.

First Alternative

The same course design as above might be used, with the following exception: While a block of students would still be considered homogeneous as to background and ability, there would be differences between groups. A progress rate factor from a user-provided probability distribution would be assigned to each group upon entry. This factor would then be used to calculate the amount of time a particular block of students would take to complete each learning event.

Second Alternative

This second course design might then be altered to keep the new progress rate factor associated with each block of students but, rather than have it affect the students' rate through a particular event, the new decision rule might be that students with certain rates or higher would skip certain events altogether. Some more information would have to be supplied with each event, namely, whether it was a skippable one based on the above factor, and the values that would qualify a block of students for skipping.

These examples were chosen from the simplest end of the spectrum, merely to provide an insight into the general capabilities of the model. The following section goes into more detail, giving a list of the characteristics that may be used to describe each of the elements of the basic model, and explaining the effect of each option on the pattern and rate of student flow through a course.

CHARACTERISTICS OF THE BASIC ELEMENTS OF THE MODEL

Teaching strategy will always directly affect decision rules. In those cases where the planner will have some control over the other elements, some of their characteristics may also be influenced by teaching strategy. The following general background on teaching techniques precedes the characteristics of the basic model elements in order to provide a context within which they may be more clearly understood.

In pursuing a full and variegated menu of potential teaching strategies for simulation, it will be necessary to consider many techniques. Following are some examples of basic and commonly accepted tactics.

Adapting course content to some student characteristic, such as ability or background, means that not all students will study the same material. The range of possible differences is quite large. For example, the addition of one remedial learning event to a course would qualify the course as using this technique. Another course might have multiple tracks of course material for students to learn, depending on their initial track assignment or classification. At the extreme, each student might have a course custom-designed according to his ability, background, and goals.

Variable pacing of instruction would again depend on some student characteristic, such as ability or background. It would mean that all students would not take the same amount of time through (perhaps) the same material. Variable pacing might be used only within events, by allowing students to complete work at their own pace, or it might be extended further to allow them to continue to the next event when they are done.

Fixed scheduling of standard material to be learned together might then apply to mass events that have been interspersed with individual instruction. These might require that all students, or some selected subset, be present at a particular time. This time might be predetermined, in which case other student activity would have to be scheduled around the mass events. On the other hand, individual student progress might be used to schedule mass events dynamically, as enough students become ready for them.

The characteristics that may be inputs to the model are starred in the following lists.

Student Population

The student population would be described and defined in the model in terms of the:

*1. Rate of student entity entry into the course.
2. Number of students which each entering entity is to represent (to move together through the course). For example, a rate of entry of 1 entity per N time units, with each entity representing 40 students, or a rate of entry of 40 entities per N time units, with each entity representing 1 student, would be considered different possibilities reflecting the intentions of the planner. The former would have to move as a single unit, while the latter would consist of 40 possible patterns of movement.
*3. Background and ability characteristics. These could be independent of each other or not, as the planner wished. They could be provided through N-point pairs probability distribution, or a matrix, or through actual data records of student capability characteristics, converted to specified formats.
*4. Records of all prerequisite learning events completed before entry into the course.
5. Records of all prerequisite learning events completed since entry into the course. These would be listed and followed by learning event number, with the event numbering scheme used by the planner being mapped to a simple sequence of integers.
*6. Several dummy variables for describing the student population, so that the planner can, if desired, make flow pattern or rate depend on other student characteristics such as age or class level.
7. Learning event now occupying the student entity.

8. Learning event last completed.
9. The number of parallel event series interruptions which this student has pending (explained in the sections on course characteristics and decision rules).
10. Number of any event that was interrupted to attend this event.
11. Time when this event will be completed by the student.
12. Time of the student's next prescheduled special event, if any.

The Course and the Instructional Resources

The characteristics of the course will be defined in the model entirely in terms of the characteristics of its events. Resources are associated for the most part with events and are therefore listed here.

The events should be input to the model in some order that is meaningful to the planner. This is necessary because the order may be used to establish sequencing when no other sequence is dictated by the decision rules, especially when multiple starting or continuation points are not allowed and parallel sequences have not been specified.

The following information is needed for each learning event:

*1. An identification number provided by the planner.
2. An identification number provided internally.
*3. An instruction type related to the content, such as:
   a. presentation
   b. examination
   c. review
   d. demonstration
   e. drill or exercise
*4. The rule, if any, for skipping this event, such as:

   Skip if (ability/background/dummy variable 1/dummy variable 2) $(</\leq/>/\geq/=/\neq)$ (some planner-provided constant).

*5. A list of prerequisite events to be taken before this event may be attempted. Where there is no prerequisite for more than one event, multiple course starting points are implied. Where two or more events have the same prerequisite, parallel event sequences are possible. In order to exploit these possibilities for variable sequencing, the planner must specifically elect to do so. See the Decision Rules section.

*6. The minimum number of students who may start a particular event together.

*7. Maximum number of students who can be accommodated in one section, where a section is defined as the new start of a particular event by one or more students, as specified by the minimum and less than or equal to the maximum. Each section needs one set of resources.

*8. Maximum number of sections that may be started upon demand.

*9. The types and quantities of resources required for one section of this event--a set of resources.

10. Number of students now in this event.

11. Number of sections of this event now under way.

12. Number of students waiting for this event, because of any constraint.

*13. Average time for a student to complete this event.

14. Maximum time, if any, that a student may remain in this event.

Available Resources. In addition to the statement of resources required for each separate event, the planner is asked to specify available resources by resource type (they may be specified as unlimited, if desired). The planner may specify the number of resources needed for each event, independently of the number of resources actually available in the system, and thus determine the adequacy of the available resources.

Decision Rules

Many of the decision rules are outputs of the strategy questionnaire. The user is asked to specify his selection of operational rules only when previous selections require further specification. The following list is merely an enumeration of the rules, and does not attempt to give the logical order that would be required for input.

1. Where the planner's specifications indicate that he will allow several parallel sequences of instruction, he will state the maximum number of such sequences that may be started concurrently. For example, suppose that he has specified five equally valid points that may follow completion of the first event; he might specify that they be taken one at a time, in any order, or might allow two at a time when one of them has previously been blocked, etc.
2. Whenever a queueing situation might arise--and the user will have these possibilities enumerated for him--the decision must be stated whether or not the student would join a queue, and under what circumstances. It might depend, for instance, on the number of students already in the queue, or perhaps on the number of available events that he is eligible to take instead.
3. If any prescheduled events are to be included in the course, the planner must specify them by number and give each a time. He must then decide what to do about events that would overlap the time of any such special event. Should the events not be started unless they can be completed, or should they be started and interrupted by the special event? If interrupted, should they be resumed at the point of interruption or be restarted?
4. Whenever any events are included in the course that require more than one student to start, the planner must decide what to do about students who are ready to start before the minimum number of other students are ready. Should they wait, study, take another event to interrupt it, etc.?
5. Whenever a student is waiting or has free time, the planner must decide what kind of resources this will involve, e.g., study halls, libraries, recreational or personal quarters, etc.
6. The planner must specify whether all events will be taken by all students. If not, he must indicate those student characteristics or model states which will determine those events to be skipped and which students

shall skip them. This indication will be given as described above under the Course and the Instructional Resources.

7. The planner must decide whether "failures" are to be simulated and, if so, whether they should be dropped from the course or recycled. If recycled, how many times? And what is the failure criterion?

In order to retain maximum generality and usefulness, the student flow model is not being described by standard education-oriented instructional terms. Such a term would be "grouping," which is not offered by name as an input option, but which the planner can readily simulate by selecting the appropriate student descriptions and decision rules. It was deemed more important to enable the planner to simulate any desired technique or combination of techniques by selecting from the various decision rule options, than to provide him with a necessarily limited set of ready-made techniques. He should, however, be provided with documentation making clear the combinations of simulation inputs that will allow him to simulate the standard cases.

Development of the model is now under way.

GLOSSARY

Appropriate communication medium: Any communication medium that can carry the message. There are eight classes of communication media, including such specific examples as film, TV, audio tape, radio, and books. Each class is appropriate to a different type of message.

Average student: The student for whom the bulk of the instruction is designed. Average refers to the student population of immediate concern to the designer. The average student in a given course may have more or less capability to learn the subject than the norm for those of his own age or experience.

Carrel: A table with shelves for books, tapes, and the like that is often partitioned or enclosed and is used for individual study.

Communication aids: Audiovisual aids such as flip charts, mockups, and Vu-graphs requiring the message sender to be present at the point of reception.

Communication medium: A self-contained means of communicating—the message sender need not be present at the point of reception.

Complex instruction: Instruction that requires student mastery of several interrelated steps, facts, or the like to attain the instructional objective, such as solving a problem, writing an essay, or checking a piece of equipment.

A lesson on the causes of the Civil War, for instance, can be relatively complex if the student is expected to comprehend the political, social, and economic situations that existed in the North and South and to understand how these situations reinforced the South's move to secession. If the lesson only requires the student to memorize a list of causes of the Civil War, however, relatively simple instruction would be involved.

Relatively complex skills typically cannot be mastered by simple, automatic drill exercises and often can be taught most effectively by giving step-by-step directions or follow-me demonstrations. See also *simple instruction.*

Constructed response: Devised by the student, who responds by producing something—speaking, writing, drawing, gesturing, using a tool, operating a machine, making something. Compare *selected response.*

Conventional instruction: Includes classroom methods such as lecture, oral quiz, guided discussion, and drill, plus the use of texts and workbooks. Also includes instructor demonstrations in the laboratory.

Discussion: Two types are considered here. (1) A relatively impromptu session set aside after a segment of basic instruction to answer student questions or to stimulate student discussion of material just covered. Not considered a separate learning event in the curriculum analysis but taken into account in the DISTAF program for determining instructional strategy. (2) A learning event prepared primarily to teach students to converse and interact in a group; considered as Type II instruction, interactive skills.

Drill: An activity intended to help the student learn a relatively simple skill by repeated, relatively automatic response to a stimulus, which is usually provided externally as in typing from printed or written text or repeating the pronunciation of foreign words. The student provides his own stimulus in most independent study. See *practice.*

Evaluation: Any measurement or assessment of student achievement, formal or informal. A quiz, test, performance test, or final examination, used to measure student progress and, in some instances, to regulate advancement from unit to unit or section to section.

Event, learning: See *learning event.*

Examination: A formal evaluation.

Facilities: See *special facilities.*

Fixed-duration programs: Media presentations that occupy a fixed (invariant) period of time; films, television programs, and audio tapes are examples. Anything that "runs" essentially without interruption and whose pace or content cannot be changed from the outside. A user cannot ordinarily go back over the material or select material at random from within the program as he can, for example, with books and workbooks. See *internal random access.*

Follow-me instruction: A step-by-step demonstration of procedures which students copy or which students practice following step by step. Such instruction applies only to individual skills and is used in either Type II or Type III instruction.

Internal random access (IRA): Required when the individual needs to study a presentation, as distinguished from merely attending to it, with or without response. Full IRA provides the following controls: start, stop, freeze-frame in the case of motion-visual media, fast forward, fast reverse, and some kind of indexing system. Partial random access may lack freeze-frame and/or indexing. Conventional textbooks have internal random access; scrambled books and filmstrips usually do not.

Learning event: Any instructional activity that can be assigned to a single subcategory of instruction. *See types of instruction.*

Materials: Media software. Either instructional aids or communication media programs (including printed materials).

Media: See *communication medium.*

Pacer: The agent that adjusts the rate of stimuli presentation to fit the student's learning rate: the learner himself, the instructor, a response-paced program, or a student leader.

Performance: Instruction in which the student is learning how to do something (not simply acquiring ideas or information, but acquiring a skill). Performance denotes student activity in *Type II* or *Type III instruction.* For example, making a map is Type II performance; repairing an engine, Type III. Student responses in Type I instruction (answering questions, filling in blanks in a workbook, etc.) are not considered performance.

Practice: Student performance in learning relatively complex skills as distinguished from performance in learning relatively simple skills that we term *drill.* Practice is less repetitive and automatic than drill; a student may practice some complex skill, such as troubleshooting or writing a business letter, only a few times during the course and may have a slightly different assignment each time. The presentation of stimuli is less important for practice than for drill, but the demonstration of skills to be learned is more important.

Presentation: Any communication to the student. Includes transmitting facts or concepts; demonstrations; giving directions; supplying stimuli for drill; describing problems to be solved.

Remedial instruction: Instruction intended to assist students who fail to master a particular lesson or learning event, as opposed to review or makeup sessions.

Response-paced programs: Instructional programs that can be presented by any medium if they are used in such a mode that the program contains integrated response stimuli, and stops after each unit of presentation (or frame) to allow the learner to select a response, then proceeds to the next unit of presentation only when the correct response has been selected. Most simple teaching machines (without branching) present response-paced programs. Since student responses must be sensed and evaluated by machine, constructed responses cannot be used; machine scoring and recording are possible, however.

Review: An abbreviated version of earlier instruction to refresh the learner's memory or skill in preparing for an examination. Not listed as separate learning events in the curriculum analysis; MODIA automatically accounts for them on the basis of stated strategy.

Scheduled instruction: Instruction designated for a specific time and place.

Selected response: Student responses selected from among two or more answers, or placing a list of items in some correct order. Multiple-choice, true-false, matching, and ordering all call for selected responses. Compare *constructed response.*

Simple instruction: Instruction that does not require the student to master several interrelated steps, facts, or the like. Activities that characterize simple instruction include memorizing foreign words, learning multiplication tables, plotting points on a graph, target practice, or sending code. Action verbs that typify relatively simple instruction in the cognitive domain include: name, list, spell, identify, choose, find, select, and match. Relatively simple skills are those that the student can typically master by fairly routine, repetitious, or automatic drill.

Note that these may not be simple skills for *some* students whose background is deficient. Therefore, determining whether the instruction is simple or complex depends on the level of average student capability as much as it does on the skill itself. See also *complex instruction.*

Special equipment: Equipment (or other materials) students must work with other than the traditional paper and pencil, drawing instruments, slide rules, or other small implements. Such materials (1) are so expensive and fragile (such as precision measuring instruments) or dangerous (such as corrosive acids) that a monitor or other responsible person must supervise student work or (2) require special facilities. Projectors, playback devices, and the like, that are used for communicating with the student are not covered by this term unless they themselves are the subject of study.

Special facilities: Areas that differ from a conventional classroom, such as workshops, laboratories, hangars, playing fields, and gymnasiums.

Team: Two or more individuals who work together. In our sense, the people playing a two-handed game form a team as do the people using a transit and chain to determine the placement of a survey marker.

Tracks: Subdivisions of a class group homogeneous with regard to student capability and the special curricula they follow. Students generally remain in the same track throughout a course.

Types of instruction: A broad categorization of instructional activity intended to aid system design.

Type I instruction: Requires no student use of special equipment and no student performance in special facilities. In addition, students are not acquiring skills (cognitive, psychomotor, motor, or social) through drill or practice. Type I activities typically occur in the classroom and concern the presentation of facts or concepts for the student to master or the presentation of goals or objectives to motivate him with a sense of direction for his learning. Frequently includes affective objectives (such as changes in attitude toward the subject) and demonstrations. Such instruction involves presentations, and may or may not contain integrated stimuli that require overt student responses.

Type II instruction: Like Type I instruction, requiring no special facilities or equipment for student performance; however, students master skills that require drill, practice, or performance. The student learns to make particular responses when provided with directions and stimuli. Activities are those in which the student must do something besides answer questions. Also includes the presentation of models of skills to be mastered (even though no student performance may be required during the demonstration) because demonstrations are frequently given immediately preceding or concurrent with student performance. Therefore, it may often be convenient to use the same means to present the models as those used to present directions for performance or actual drill stimuli. If a performance model is to be given but *not* immediately preceding or concurrent with the drill, practice, or performance session, it may be categorized as a demonstration under Type I instruction. Type II instruction can include pure skill demonstrations (with no student response); follow-me demonstrations in which the students perform each step as they are directed or as it is presented; presentation of directions and stimuli for performance; and pure performance (with no presentation to the student).

Type III instruction: Any instructional activity that requires the students to work with special equipment (such as a simulator, a piece of machinery, or a musical instrument) or in a special facility (such as a shop, a laboratory, a parade ground, or other special area) or both. See *special equipment* and *special facilities*.

The instructor is *not* using Type III instruction when he uses special equipment (such as a projector or mockup) to demonstrate a procedure or to clarify a concept (such as operating aircraft flight controls), unless the students are also *required* to use the same equipment at the same time (or immediately afterward). The rules for classifying performance models and presentations for Type II instruction are the same as those for Type III instruction, namely, if the model immediately precedes or is concurrent with student performance, it is most conveniently treated as Type III instruction; if the model will be separated in time from student performance, it may be treated as Type I instruction.

Variable pacing: The rate of stimuli presentation to the student or student group varied on the basis of student response. Pacing may be varied to fit each individual student's learning rate or to fit the learning rate of a group. The use of response cards or other group response devices can facilitate group pacing, although often hand or voice responses to the instructor's questions can be used for the same effect.